DROUGHT RESISTANCE MECHANISMS AMONG PEANUT GENOTYPES

BY

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Dedicated to my father, José
my mother, Antonieta (in memoriam)
my husband, Luis,
my daughters, Juliana and Alice
and my brother and sisters.

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Peanut (Arachis hypogaea L.) genotypes Pearl Early Runner (PER), PI 383426 (PI), Early Bunch (EB), and Florunner (FLR) were grown in field plots and in greenhouse tubes to study their response to drought.

Two irrigation treatments were imposed in the field experiment: optimum irrigation throughout the crop cycle, and optimum irrigation except during 59 to 88 days after planting. Measurements were taken for: stomatal diffusive resistance (SDR), leaf water potential components, leaf area expansion, rooting density versus depth, soil water status, and yield.

In the greenhouse, length of taproot and node progression were recorded on plants grown in soil in clear acrylic tubes. Leaf area, root density, dry weight of leaves, stems, and roots were measured at 61 days of age.

In the field the genotypes differed in the extraction of water at deeper depths. Pearl Early Runner extracted less water at deeper layers and therefore wilted and closed its stomata sooner.

Plants of PER in the stressed plots had higher values of SDR and lower values for all water potential components throughout the drying cycle.

Leaf area expansion and growth of the cotyledonary branch were reduced by drought for all genotypes but PER was affected the most.

Root density of PER was also reduced most by drought especially at the deeper depths. This genotype had the largest yield reduction in response to water stress.

In the greenhouse experiment, the genotypes differed in the rate of taproot elongation and in the rate of node development on the main stem. There were differences in root weight and density at various depths, but PER had the lowest values, especially below 60 cm. The root to shoot ratio was highest for EB and lowest for PER.

The results suggest that the wilt susceptible PER allocates more photosynthate to shoot growth but less to root growth, especially at deeper depths. Since stomatal response to internal water status in PER was not different from other genotypes, its earlier wilting, lower turgor, reduced growth, and stomatal closure under drought conditions appear to be caused by differences in root growth and extraction of water from the soil.

INTRODUCTION

Drought is a problem in many agricultural areas of the world and traditionally agriculture has alleviated the water deficit problem by irrigation. However, irrigation is expensive and may not be sufficient for extending crop production into semi-arid areas where water is limited. One objective of crop physiologists and breeders is to select genotypes that have some type of drought resistance mechanism together with other desirable characteristics such as high yield potential and pest resistance. Kramer (1969) defines drought resistance as the various means by which plants survive periods of environmental water deficit.

Drought resistance in plants can be achieved by several mechanisms and may be due to tolerance or to avoidance of water stress (Kramer, 1969; Levitt, 1980). Among economically important plants, tolerance seldom seems to be the deciding factor in their drought resistance, and usually drought tolerance can be a factor only if accompanied by drought avoidance. Water stress avoidance involves mechanisms to either reduce water loss or increase water uptake, like changes in leaf orientation or shape, stomatal closure and enhanced water uptake by the roots. Drought avoidance permits the plant to maintain a high internal water potential in spite of the low environmental water potential to which it is exposed. The plant avoids a decrease in cell water potential and, therefore, maintains sufficient water content and turgor pressure for growth.

Several researchers have evidence to support the drought-resistant nature of peanuts (Arachis hypogaea L.). The Spanish-Valencia group of peanuts is considered more resistant than the Virginia runner group. For Spanish type peanuts, the growth stage most sensitive to water deficits was reported by Klepper (1973) to be 6 to 8 weeks after sowing, which corresponds to the elongation of pegs into the soil and formation of pods. Levitt (1980), analyzing data of Slatyer (1955), classified peanuts as drought-resistant due to avoidance rather than to tolerance, and suggested that the avoidance factor was the greater water uptake by the root system.

The objectives of this work were to compare the drought response of four peanut genotypes and evaluate the following:

1. The water relations of these genotypes in response to soil water deficit imposed during peg elongation and pod formation.
2. The water extraction capacity and rooting pattern, in the field, of the root systems among the genotypes studied.
3. The growth of the peanut roots in acrylic tubes under greenhouse conditions.

LITERATURE REVIEW

The availability of soil moisture affects plant growth rate by altering the supply end of the water potential gradient and subsequently the water potential of the leaf. Growth occurs whenever leaf water potential rises above that which supplies minimum turgor (Boyer, 1968).

Turgor affects a number of cellular processes. Cell enlargement is markedly reduced when turgor drops even a small amount (Cleland, 1967; Boyer, 1968; Boyer, 1970; Green et al., 1971) and stomatal movements respond to it (Zelitch, 1969; Bennett et al., 1981). However, turgor has little effect on leaf photochemical activity (Boyer and Potter, 1973).

Hsiao (1973) suggests that decreasing the external water potential by only 0.1 MPa or less results in a perceptible decrease in cellular growth. This event is usually followed by a reduction in cell wall and protein synthesis. At slightly more negative water potentials, protochlorophyll formation is inhibited followed by decreases in activities of certain enzymes. At levels of stress that cause observable changes in enzyme activities, cell division is also inhibited, and the stomates begin to close, leading to a reduction in transpiration and photosynthesis.

At higher levels of stress, respiration, translocation of assimilates, and carbon dioxide assimilation drop to levels near zero. Plants usually recover if watered at this point, although growth and photosynthesis in young leaves may not reach the original rate for several days, and old leaves may be shed (Hsiao, 1973; Salisbury and Ross, 1978).

Plant and Soil Water Relationships

Bennett et al. (1981) examined the changes in components of leaf water potential of peanut leaves during desiccation of detached leaves and also during natural soil moisture deficits imposed in the field. In detached leaves of Florunner and Early Bunch, it was apparent that as water potential (ψl) decreased the leaves approached zero turgor potential (ψp) at similar ψl of about -1.25 to -1.28 MPa. When ψl decreased below -1.30 MPa, negative values of ψp were calculated. According to Boyer and Potter (1973), these values probably represent zero turgor because the artifactual negative values are a result of underestimation of ψs because of dilution of the cell sap by extracellular water after the freezing and thawing of the tissue. Meanwhile, the construction of a pressure-volume curve, which permits ψp to be calculated without introducing the dilution error, showed similar values of zero ψp indicating that the dilution effect on osmotic potential (ψs) was relatively small.

When studying the stress imposed in the field, the same authors (Bennett et al., 1981) noticed that zero ψp was attained at lower values of ψl than in detached leaves and could have resulted from some osmotic adjustment of the plants. They concluded that the relationships of ψp, ψl, ψs and relative water content (RWC) of peanut leaves were similar to those of leaves of other crops and that these relationships conferred no unique drought resistance advantage to peanut.

Wenkert et al. (1978) and Zur et al. (1981), working with soybean, provided additional evidence that the point of zero turgor potential is reached when only a small fraction of leaf water is lost. They observed that the osmotic fraction of the total water content is approximately 70%.

Gautreau (1977) reported leaf water potential values for several cultivars of peanuts. The water potentials obtained were compared to the ability of the varieties to withstand drought and yield well. The varieties best adapted to the dry zones had the lowest leaf water potential. Gautreau (1977) concluded that leaf water potential accompanied by determinations of parameters such as saturation water deficit, leaf diffusion resistance, and transpiration should allow peanut cultivars to be classified in order of adaptation to drought, taking into account the length of the crop cycle and the yield potential.

Leaf water potentials of irrigated and induced-drought peanut plants were measured under field conditions by Allen et al. (1976), using _in situ_ leaf hygrometers. They found that water potentials of about -1.2 MPa are common for well-watered peanut plants under meteorological conditions of high evaporative demand.

Effect of Water Deficit on Stomatal Behavior

Increased stomatal resistance as a plant response to water stress has been reviewed (Turner, 1974; Begg and Turner, 1976). Generally, there is a leaf water potential range below which stomatal closure occurs.

Bhagsari et al. (1976) reported two trials where they examined the effects of moisture stress on photosynthesis, transpiration, relative water content and diffusive resistance of peanut plants. Three genotypes of peanuts were grown in pots in a greenhouse in the first test, and two genotypes were grown outside in pots in the second test where soybean was included for comparison. The moisture treatments consisted of completely withholding water from the stressed plants while the controls were watered twice a day. Net photosynthesis, relative water content, and diffusive resistance of Florunner peanut on the sixth day of water stress in test one were 7.3 mg CO_2 dm^{-1} h^{-1}, 30.5%, and 21.0 sec cm^{-1}, respectively, for the stressed plants, while for the control plants the values were 32.8 mg CO_2 dm^{-2} h^{-1}, 90.5%, and 1.2 sec cm^{-1}. The other two genotypes showed similar trends.

The results from the second trial (Bhagsari et al., 1976) showed that on the third day of stress the relative water content decreased, the diffusive resistance increased dramatically, and this response was associated with large reductions in photosynthesis and transpiration. Increases in diffusive resistance appeared to begin when relative water content dropped below 80%. The highest average diffusive resistance values reached in stressed plants were about 20 to 30 sec cm^{-1} in experiments 1 and 2, respectively. Comparison of the data of peanut with those from soybean and also with published data led Bhagsari et al. (1976) to conclude that photosynthesis of peanut is affected by water stress in a manner similar to that of other crop species, and that any superior drought resistance exhibited by peanut must be due to other factors.

The influence of soil water and solar radiation on the stomatal diffusion resistance of Florunner peanuts was examined by Allen et al. (1976). The plants were grown in Lake fine sand, and subjected to drought by covering the plots with plastic shelters for 20 days. After seven days with the shelters there was very little difference in stomatal resistance between the dry and irrigated plots, with no midday or midafternoon stomatal closure. The stomatal resistance was 1.05 and 0.83 sec cm^{-1} for the dry and irrigated plots, respectively. After 17 days of stress treatment, the stomatal resistance in the dry plots increased to about 10 sec cm^{-1}. By this time the plants had stopped growing, flowering had ceased, and gynophore penetration had discontinued. Allen et al. (1976) concluded that peanuts appeared to resist drought conditions because the plant roots extracted soil water to depths of at least 180 cm in sand soils. Also, the peanut plants protected themselves against excessive transpiration both by closing stomata and by folding their leaflets in a manner which greatly reduces the interception of direct beam solar radiation.

The effect of atmospheric saturation deficit on the stomatal conductance of peanut plants grown in a glasshouse was investigated by Black and Squire (1979). The results demonstrated that the stomatal conductance of well-watered plants was affected strongly by changes in saturation deficit from 1.0 to 3.0 KPa. However, this stomatal response to saturation deficit was reduced or absent in unirrigated plants in which stomatal conductances were reduced.

Pallas et al. (1979) investigated the effect of five drought treatments on the leaf diffusive resistance of peanuts grown in rainfall protected plots. All plots were watered from zero to 35 days which corresponds to germination and the early vegetative developmental period. The peanut plants were subjected to drought at 36 to 70, 71 to 105, 105 to 145, 36 to 105, or 71 to 145 days of age by the withholding of irrigation. The early season 35-day drought had little effect on leaf diffusion resistance. However, the extended (70 days) early season-droughted plants showed a five-fold increase in leaf diffusion resistance by the end of the drought. The leaf diffusion resistance of midseason 35-day-droughted plants increased twelve-fold in the lower epidermis and five-fold in the upper epidermis at 105 days of age, as compared to the control. After watering, the diffusion resistance returned to that of the controls. The late season short drought did not increase leaf diffusive resistances but the midseason extended droughted plants showed a two-fold increase in leaf diffusive resistance by the end of the season.

According to Pallas et al. (1979), peanut leaves have the ability to rehydrate quickly and, after irrigation, leaf resistance recovers more rapidly than that of other crop species. Boote et al. (1982) suggested that this ability to rapidly recover stomatal function upon relief of water deficit may be an important adaptive response of peanut plants to drought.

Root Growth and Water Uptake

According to Kramer (1969), one of the most effective safeguards against drought injury is a deep, wide-spreading, much-branched root system. A combination of a potentially deep-rooting plant and soil conditions favorable for deep rooting is likely to provide conditions advantageous for drought avoidance.

Variation of root characteristics within species has been reported for some crops. Hurd (1968) and Hurd (1974) found differences in rooting patterns among wheat cultivars. The cultivars differed in root lengths, dry weight of roots at various soil depths, and extent of rooting in the seedling stage. The rooting patterns were related to differences in drought resistance. Deeper rooting varieties yielded better under drought stress.

Rice cultivars were found to have extensive diversity in rooting depth and density. Upland cultivars, which are more drought resistant, have a deeper and more prolific root system than low land cultivars (O'Toole and Cruz, 1980; Steponkus et al., 1980).

In sorghum genotypes, drought resistance was found to be associated with greater root weights, deeper root systems, and higher root/shoot ratios (Nour and Weibel, 1978; Jordan and Miller, 1980).

The literature shows evidence that the rooting depth of peanut plants may be an important drought avoidance mechanism (Stansell et al., 1976; Robertson et al., 1980).

Stansell et al. (1976) examined peanut responses to soil water variables using field plots which were sheltered from rainfall, and found that extraction of water from profile depths greater than 60 cm begins by about 75 days of age. They emphasized that the ability of peanuts to utilize water at such depths explains, to some extent, their ability to withstand extended water stress. Their results (Stansell et al., 1976) also showed water extraction to a depth of 106 cm for all three varieties of peanuts studied, including Florigiant, Florunner and Tifspan.

Robertson et al. (1980) studying the relationship of irrigation and root distribution of peanuts grown on sandy soils reported that peanut root length was not affected by water management, and that it was evident that roots penetrated deeper than 150 cm in fine sandy soil. They also observed that root length density was less in the 30 to 45 cm soil layer than above or below that zone, probably due to a tillage pan which created a physical barrier for root development. Allen et al. (1976) found water extraction to as deep as 180 cm in these soils.

The effect of moisture stress on response of peanut to phosphate was evaluated by Narasimham et al. (1977). The length of taproot was not much affected by moisture regimes (25, 50, and 75% depletion of available moisture), but the spread of the lateral roots was considerably reduced with an increase in moisture stress.

Some evidence indicates that soil matric potential and soil water content affect root elongation rates of crop plants (Peters, 1957; Mederski and Wilson, 1960; Taylor and Gardner, 1963; Stevenson and Boersma, 1964).

The root elongation rate of peanut as a function of soil strength and soil water content was studied by Taylor and Ratliff (1969). The soils were wetted to 7.0, 5.5, and 3.8% water which corresponded to -0.019, -0.042, and -1.25 MPa of soil matric potential. Their results (Taylor and Ratliff, 1969) indicated that water content per se did not affect the relationship between peanut root elongation rate and penetrometer resistance. However, the wet weight and height of plant tops were significantly affected by soil water content even where the plant roots were not restricted by high-strength soil.

Robertson et al. (1979) reported the root distribution of five crop species including peanuts grown in fine sands. On the basis of length per unit weight of root, the peanuts had the highest mean value when compared to the other crops.

Differences in rooting depth among and within Spanish and Virginia type peanuts were found by Bhan (1973). There were also differences in number of primary and secondary roots and in root weight. The total dry weight of roots was significantly correlated with shoot weight. Bhan (1973) also reported significant linear correlation between root depth, number of roots, dry weight of roots, and peanut pod yield.

Genetic variability in root growth characteristics of peanuts was examined by Ketring et al. (1982). They compared root growth of 23 genotypes grown in acrylic tubes in a greenhouse experiment, after 55 days from planting. Among the Spanish types, Spancross had the longest taproot, and largest leaf area and shoot dry weight. Among the Virginia types, Florunner and UF 77318 had the longest taproots, followed closely by Early Runner, Early Bunch, and Florigiant. Early Bunch plants had the largest dry weight, leaf area, and number of roots at the 1-m depth.

Linear correlations between shoot and root growth parameters showed that number of roots and length of roots were highly correlated in the Spanish genotypes but not in the Virginia selections.

The authors (Ketring et al., 1982) concluded that there was considerable diversity in root growth among the peanut germplasm examined, and they suggested that selection among peanut genotypes for rooting characteristics can improve drought resistance and nutrient uptake of the crop.

Taylor et al. (1978) found differences in taproot growth rate and root length of soybeans. Significant linear correlation was found between shoot weight and taproot length.

Effects of Water Deficits on Stem and Leaf Growth

Water stress affects practically every aspect of plant growth and can modify the anatomy, morphology and physiology of plants, causing a general reduction in size of the plants (Kramer, 1969). The reduction in cell turgor is the most important cause for reduced plant size, but water stress affects nearly every process in a plant, and other factors in addition to turgor are involved.

Specifically for peanuts it has been shown that water deficit decreases production of dry matter (Su et al., 1964; Lenka and Misra, 1973; Stansell et al., 1976; Vivekanandan and Gunasena, 1976; Pallas et al., 1979), reduces leaf expansion and stem growth (Allen et al., 1976; Vivekanandan and Gunasena, 1976), and causes modifications in stem and leaf morphology (Su et al., 1964; Gorbet and Rhoads, 1975; Boote and Hammond, 1981).

When peanut plants cultivated in wooden boxes suffered drought for the whole period of growth, the weight of the dry vine was 48 g plant^{-1} against one control of 157 g plant^{-1} (Su et al., 1964). The other values were 150, 146, 158, 161, and 145 g plant^{-1} for the treatments incurring water withholding during 10 to 29, 30 to 49, 50 to 69, 70 to 89, and 90 to 109 days of drought, respectively. The height of the plants was also reduced in all treatments except for the 10 to 29 day treatment.

Water deficiency in the deeper profile resulted in some reduction of vine dry weight at harvest (Stansell et al., 1976). The largest reduction in vine dry weight of Florigiant, Florunner, and Tifspan peanuts occurred where irrigation was scheduled only after plants wilted and did not recover overnight.Vine weight of Florunner peanut was not decreased by any 35-day drought, but was reduced by 70-day droughts. The control treatment produced 4687 kg vine ha^{-1}, and the lowest value was 3775 kg ha^{-1} for the late 70-day drought treatment (Pallas et al., 1979).

Allen et al. (1976) reported that Florunner plants subjected to drought, in field conditions, stopped growing and new leaves ceased to expand at the stem apex. However, 11 days after drought ceased, the plants were growing rapidly and the induced-drought plots had almost as much canopy cover as the irrigated plots.

Drought which occurred during early pegging and pod formation reduced vegetative growth by reducing the rate of node formation and elongation growth. Stressed plants remained 3 to 5 nodes shorter (delayed) than irrigated plants even after watering was resumed (Boote and Hammond, 1981).

There is evidence in the literature (Il'ina, 1958; Lin et al., 1963) that peanut plants subjected to extended soil moisture deficit have fewer and smaller leaves, which have smaller cells. Vivekanandan and Gunasena (1976) reported that leaf area index and leaf area duration of peanut plants were reduced by decreasing the soil moisture potential from -0.033 to -0.073 MPa. The maximum value of leaf area index recorded for the wet treatment was 6.25, followed by 4.75, and 3.81 for the intermediate (-0.053 MPa) and dry treatments, respectively. The leaf area duration was diminished 28 and 40%, respectively, when compared with the wet regime.

Effect of Water Deficit on Flowering and Fruit Development

Norden (1980) stated that the peanut plant is indeterminate in growth, and that flowering begins 25 to 35 days after planting, depending on the cultivar. The most prolific period of flowering occurs between 6 and 11 weeks, depending on the cultivar, with a high proportion of the first flowers producing mature fruits. This difference between early or full season cultivars can help us to understand the apparent controversy in the peanut literature concerning which growth phases are most sensitive to drought. For example, Klepper (1973) reported that the period of greatest sensitivity of Spanish type peanuts to drought occurs 6 to 8 weeks after planting, while Pallas et al. (1979) working with Florunner peanut indicated that yield reduction was greater the later the drought occurred in the season.

Billaz and Ochs (1961) found that water stress at 50 to 80 days after planting reduced flowering and pegging and induced a greater yield reduction of Spanish type peanuts than stress at any other growth stage.

Gorbet and Rhoads (1975) reported that when water stress occurs during the season, flowering is reduced and occasionally stops completely. When water is supplied in the form of rain or irrigation, the plant responds with new growth and flowering. The mechanism responsible for reduced flower number in water stressed plants is not very clear, but may be similar to leaf and node reduction, and may be due to more than shortage of photosythate (Boote et al., 1982).

Peg and Pod Development

The literature contains several references to the effects of moisture deficit on fruit production in peanuts. Generally, pod number is more affected than pod weight (Underwood et al., 1971; Lenka and Misra, 1973; Ono et al., 1974; Boote et al., 1976; Vivekanandan and Gunasena, 1976; Pallas et al., 1979). The number of pegs and pods decreased with a decrease in frequency of irrigation, which was applied at 25, 50, and 75% depletion of available water, in a field experiment conducted by Lenka and Misra (1973). The number of pods plant^{-1} was 17.9, 16.2, and 13.7, respectively, for the three irrigation treatments.

Florigiant and Florunner cultivars of peanut produced more pods with irrigation, especially in dry seasons (Gorbet and Rhoads, 1975).

Lack of water in the soil reduces pod number in three ways as pointed out by Boote et al. (1982). The first cause is that water deficit in the fruiting zone reduces peg penetration and therefore prevents fruit formation (Cox, 1962; Underwood et al., 1971; Ono et al., 1974; Boote et al., 1976). The second cause is from low turgor pressure inhibiting peg elongation, fruit expansion and pod addition (Bhagsari et al., 1976; Boote et al., 1976). A third factor is shortage of photosynthate limiting the number of pods added and occurs because moisture deficit reduces photosynthesis (Bhagsari et al., 1976).

The effect of water deficit occurring during seed growth of peanuts was studied by Pallas et al. (1979). They reported that peanut plants subjected to water stress from 71 to 105 days of age had a yield of 3666 kg ha^{-1} compared to the irrigated control which yielded 5464 kg ha^{-1}.

The water stress that occurs after a full fruit load is set reduces yield by causing smaller and younger fruits to terminate growth and eventually by reducing growth rate of the older fruits (Boote et al., 1982).

Skelton and Shear (1971) subjected the Virginia Runner peanut cultivar to four combinations of calcium and water (presence or absence) in the fruiting medium. The various treatments did not affect the number of gynophores produced by the plants, but there was a significant difference between treatments in the percentage of gynophores alive. The treatment where calcium and water were added had the lowest percentage of dead gynphores. Also, the greatest percentage of gynphores showing fruit development occurred where both calcium and water were available. Where calcium was added and water omitted, none of the one-segmented fruit contained normal seed and most of the two-segmented fruit contained only one seed.

Su et al. (1964) studied the effect of drought treatments at different growth stages on peanut plants growing in waterproof boxes. The weight of seeds per plant was highest (18 g) for the 10-to-29-day periods of drought and lowest (3.18 g) for the unirrigated treatment. The control (whole period irrigated) produced 15.4 g of seeds per plant and the 50-to-69-day period of drought produced 8.18 g per plant. They concluded that the growth period most susceptible to drought was the period centered at the peak flowering stage which occurred about 50 days after sowing.

MATERIALS AND METHODS

Field Experiment

General Description of the Field Experiment

The experiment was conducted at the Irrigation Research and Education Park located on the University of Florida Agronomy Farm in Gainesville.

The soil is a Kendrick fine sand, (loamy, siliceous, hyperthermic Arenic Paleudult) and individual main plots were provided with sprinkler irrigation. The plots were fertilized with 784 kg ha^{-1} of a 0-6-25 (N-P-K) fertilizer. Gypsum ($CaSO_4 \cdot H_2O$) was applied at a rate of 1120 kg ha^{-1} at 43 days after planting. Four peanut genotypes were used: Pearl Early Runner, PI 383426, Early Bunch and Florunner. The selection of these genotypes was based on a previous year's study of 10 genotypes.

The Pearl Early Runner peanut plants have a prostrate growth habit; this genotype appears drought-susceptible and shows wilting symptoms in field trials several days prior to wilting of other cultivars. It is generally low-yielding and has a white seed testa trait.

The PI 383426 plants have a bunch growth habit. This genotype visually appears drought-resistant but is also low-yielding. In 1981 trials its yield was reduced least by drought or alternatively, yield was increased least by irrigation.

The Early Bunch peanut is a high-yielding Virginia market type peanut whose plants have a spreading bunch growth habit (Norden et al., 1977).

The Florunner peanut is a high-yielding Runner market type peanut and the plants have a prostrate growth habit (Norden et al., 1969). Both Early Bunch and Florunner are widely grown and considered drought-resistant in terms of yield capability, although the large-podded Early Bunch can suffer more yield reduction under drought if the calcium supply to the pegging zone is inadequate.

The four genotypes were planted 5 May 1982 at a spacing of 61 cm, using 13 seeds m^{-1}. Balan® (N-butyl-N-ethyl-α,α,α, trifluoro-2,6-dinitro-p-toluidine) was incorporated prior to planting for weed control. The peanut seeds were treated with Captan® N-(trichloromethyl) thio-4-cyclohexene-1,2-dicarboximide just before planting, and Bravo® (2,4,5,6-tetrachloro-1,3-benzenedicarbonitrile) was applied for leafspot control as needed. Plants were harvested on 20 Sept. 1982.

Experimental Design

The experimental design was a split-plot with irrigation levels as main plots and peanut genotypes as subplots with four replications. Each main plot measured 14 x 14 m. Two irrigation treatments were imposed on the plants:

1. Optimum irrigation throughout the crop cycle. The plants were irrigated when hydraulic head reached -0.02 MPa at a 15 cm soil depth.

2. Optimum irrigation except during peg elongation and pod formation when mobile shelters were used to exclude rainfall. The shelters measured 4.3 x 4.9 m and were made of transparent polyethylene and placed over the dry plots at night and whenever rainfall was imminent. Withholding of water began 59 days after planting. Irrigation of the dry plots resumed 89 days after planting. The irrigation schedule is shown in Appendix Table 5. Climatological data were available from the Agronomy Farm Weather Station located 100 m from the plots (Appendix Table 6).

Sampling and Measurements

Leaf water potential, leaf osmotic potential and leaf turgor potential

Plant water status was determined every 3 or 4 days at midday, by measuring leaf water and osmotic potential of two leaflets per genotype per plot, using Spanner-type chamber thermocouple psychrometers (Spanner, 1951). The psychrometers were previously calibrated using sodium chloride solutions with concentrations in the range of 0.1 to 0.5 molal. Using standard tables (Lang, 1967) with water potential values corresponding to the NaCl concentrations, a leaf water potential-millivolt output curve was determined.

To measure leaf water potential, two fully expanded upper leaflets were selected in the field. From these two leaflets, three or four leaf discs were collected and immediately sealed in a psychrometer chamber. The thermocouple psychrometer and chamber assembly were placed in a water bath, at 30°C. After 4 h of equilibration, the output of the thermocouple psychrometer was recorded using a stripchart-recorder and a dewpoint microvoltmeter operating in the psychrometric mode. Leaf water potentials were determined by comparing the outputs with the calibration curves. Immediately after determination of leaf water potentials, the thermocouples were placed in a freezer at -15°C for 12 h. After this period, the samples were slowly thawed, placed back in the water bath, and equilibrated again for 4 h before output was again determined. The water potential of the sample after freezing represents approximately the leaf osmotic potential, if one assumes all water is osmotically active. Leaf turgor potential was calculated as $\psi p = \psi l - \psi s$ where ψp, ψl, and ψs represent turgor potential, water potential, and osmotic potential respectively.

Leaf stomatal resistance

Measurements of stomatal resistance of the upper (adaxial) and lower (abaxial) leaf surfaces were taken every 3 or 4 days at midday from the same two fully expanded leaflets, immediately before taking samples for water potential components. A steady-state porometer (LI-COR™ model LI-1600) was used for this purpose. It is a ventilated system which gives a fixed boundary layer resistance which is automatically subtracted from leaf diffusive resistance to give leaf stomatal resistance.

Soil water status

The soil water data were obtained every other day from mercury manometer tensiometers placed at the following depths in each experimental plot: 15, 30, 45, 60, 90, 120, and 150 cm. The tensiometers were calibrated to give hydraulic head with reference to the soil surface.

Rooting depth profile and density

Soil core samples for root measurements were collected twice, at 64 and 89 days after planting, using aluminum tubing 5 cm in diameter. At a point in the plant row and midway between adjacent plants, the tubing was driven into the soil in 15-cm increments to 60 cm and in 30-cm increments from 60- to 150-cm depths.

Samples were stored in polyethylene bags in a refrigerator until roots were counted following the techniques described by Newman (1966), Tennant (1975), and Robertson et al. (1980). The roots were separated from the soil in a stream of water on a 2-mm aluminum screen and transferred to a nylon screen of appropriate size. The nylon screen was placed over a transparency with grid lines and both were placed over a lighted glass-topped box. Finally, counts were made of the intersections of the roots with the vertical and horizontal grid lines using a hand tally counter. The complete counts were converted to length measurements using the following formula:

$R = N \times G.C.F.$, where

R = root length,

N = sum of horizontal + vertical intercepts, and

G.C.F. = grid conversion factor; 0.7857 for 1-cm grid and
1.5714 for 2-cm grid.

The root length density was calculated by dividing the length of the roots by the volume of the soil core sample (from 15- or 30-cm increments and 5-cm tube diameter), and was expressed in cm of root per cubic cm of soil.

Light interception

Midday measurements of interception of photosynthetically active radiation by the canopy were taken four times during the experiment at 65, 72, 79, and 99 days after planting using a LI-COR LI-188B™ integrating quantum radiometer with a 1-m quantum sensor bar. The sensor bar was alternately placed under the canopy diagonally across the rows and also above the canopy. The fraction of light interception was calculated by subtracting the radiation values at the ground level from the ambient radiation values and dividing by the ambient radiation.

Branch growth and leaf expansion

For these measurements one cotyledonary branch was marked per plot and its leaves were numbered as the leaves formed. At 3- to 6-day intervals, the length of the branches, the number of leaves and the dimensions (length and width) of one leaflet of all leaves were measured. At the end of the stress recovery period (99 days after planting), the marked branches were harvested and the area of each leaf (4 leaflets) was measured with a LI-COR™ leaf area meter. Then, using the values of length (L), width (W), and the actual area (A) of each leaf at harvest, one equation was determined for each one of the treatment combinations. The equation components were as follows:

$A = a + bX$, where

A = leaf area of one leaf (four leaflets),

a = intercept,

b = slope, and

$X = L \times W$.

Length and width values of leaflets were measured as the leaves developed during the stress cycle and recovery period (58, 63, 66, 71, 75, 78, 84, 89, 93, and 99 days after planting). The length and width values were applied to the developed equations in order to calculate area per leaf which was summed over all existing leaves including second order branches on cotyledonary branch to give total leaf area per branch at each measurement date. The following formula was used to calculate the total leaf area (TLA):

$$TLA = \sum_{i=1}^{n} Ai$$

where n = number of expanded leaves existing on that date.

Yield Data

At maturity the peanut plants were dug manually and the detached pods were recovered from the soil. Two rows were harvested, each measuring 3.66 m long, for each experimental plot. The peanuts from each plot were separately threshed, harvested, dried, and weighed. Dropped pods were added back to threshed pods. The following measurements were made:

1. Pod weight
2. Seed weight
3. 100-seed weight
4. Shelling percentage.

Yields of pods or seeds were expressed in kg ha^{-1}.

Greenhouse Experiment

General Description of the Greenhouse Experiment

The experiment was conducted during March and April 1983 in a greenhouse located on the University of Florida Agronomy Farm in Gainesville.

The same four peanut genotypes used in the field experiment were grown in 2-m long acrylic tubes inclined 15° from vertical, and placed in light-tight wooden boxes inside the greenhouse. The 10.16-cm diameter tubes were filled with soil collected from the field experimental site. The upper 20 cm were filled with top soil and the remaining portion with uniformly-mixed sub-soil.

A nearly air-dry soil was sieved and the tubes were filled by gently tapping and rotating the column as the soil was poured into the column. With this procedure an approximately uniform bulk density was obtained from top to bottom.

Photosynthetically active radiation (PAR) in the greenhouse was measured with a 1-m quantum sensor placed at plant level. Soil temperatures were measured with thermocouples placed in two tubes at a 15-cm soil depth. Light and temperature sensors were connected to a Campbell Scientific™ CR-5 data logger for output on paper tape.

The seeds were selected for uniformity of weight, varying ±0.03 g within each genotype, and treated with Captan®. The weights of the seeds were 0.60, 0.53, 1.00, and 0.75 g seed^{-1} for Pearl Early Runner, PI 383426, Early Bunch, and Florunner, respectively. On 23 February the seeds were allowed to germinate in Petri dishes containing four sheets of filter paper and water. After 50 h germination, three seedlings with radicles longer than 1 cm were planted in each acrylic tube, at 4-cm depth, in the greenhouse. Twelve days after planting two plants were removed by cutting off their shoots, leaving only one plant in each tube.

The peanut plants were watered with water and/or Hoagland's solution (half strength without nitrogen) usually every other day as needed to maintain a good soil environment for the roots (Appendix Table 7). Good nodulation occurred in the top soil.

Experimental Design

The experimental design was a completely randomized experiment with genotypes as treatments and five replications. The experiment was concluded 61 days after planting when the roots reached the bottom in one tube.

Sampling and Measurements

Root growth

Root growth was measured by recording the tap root length every other day on the inclined surface of each tube. When, for a given date, the taproot disappeared from the interface of soil and tube, an interpolation approach, using the values of the day before and day after, was utilized to calculate the maximum depth of the taproot on that particular day.

At the conclusion of the trial, maximum taproot length was measured within the core if not available on the interface, and the soil was extracted in 20-cm cores. The cores were placed on screens where the soil was washed out and the roots were collected for determination of root and nodule fresh weight and root length density. The taproot was sampled separately. The roots and nodules were then put in ovens at 60°C for 24 h and dry weight recorded.

Shoot growth

Shoot growth was measured by following the node progression on the main stem. Every other day the number of developed nodes (fully expanded leaves) on the main stem was counted (V stage) and the appearance of flowers and fruits (R stage) was recorded for each genotype according to the procedure of Boote (1982). At the end of the experiment the shoots were separated into stems and leaves and the leaf area was measured with a LI-COR™ leaf area meter. The leaves and stems were dried at 60°C for 24 h and weighed for dry weight of these plant parts.

Data Analysis

All field data were analyzed based on a split-plot design experiment while the greenhouse data were analyzed based on a completely randomized design experiment. Procedures of Freund and

Littel (1981) were used for the calculations of analysis of variance (ANOVA tables) and the general linear model (GLM) was used to make comparisons among treatments. Results are presented as four subgroups:

a. Changes in the water-relations and growth of four peanut genotypes during the stress and recovery periods in the field,

b. Relationships between plant water potential components and stomatal resistance,

c. Yield data,

d. Root growth data, root length density and shoot growth of four peanut genotypes grown in acrylic tubes under greenhouse conditions.

RESULTS AND DISCUSSION

Changes in the Water Relations and Growth of Four Peanut Genotypes during Induced-Drought and Recovery Periods

Soil Water

This section deals with the changes in water potential components, diffusive resistance, cotyledonary branch growth, and root length density of four peanut genotypes submitted to water withholding during peg elongation and pod formation (59 to 88 days after planting) under field conditions.

Figures 1 through 4 illustrate the hydraulic head (average of four replications) in the induced-drought plots of Pearl Early Runner, PI 383426, Early Bunch, and Florunner, respectively, from 54 to 98 days after planting (DAP) for six depths of the soil profile. Figure 5 shows the hydraulic head (average of four replications) in the irrigated plots of Florunner peanut.

The drying cycle plots were irrigated the last time at 58 DAP. Figure 1 shows that as soon as the shelters were placed over the plots (59 DAP), the hydraulic head at 15 cm started to drop, due to evaporation and root water extraction, and that within 5 days it had attained values as low as -0.08 MPa. A similar pattern of water extraction at 15 cm depth was reported by Allen et al. (1976). Extraction of water from profile depths greater than 30 cm is apparent by 69 DAP (Fig. 1). Although adequate water was available at the 90

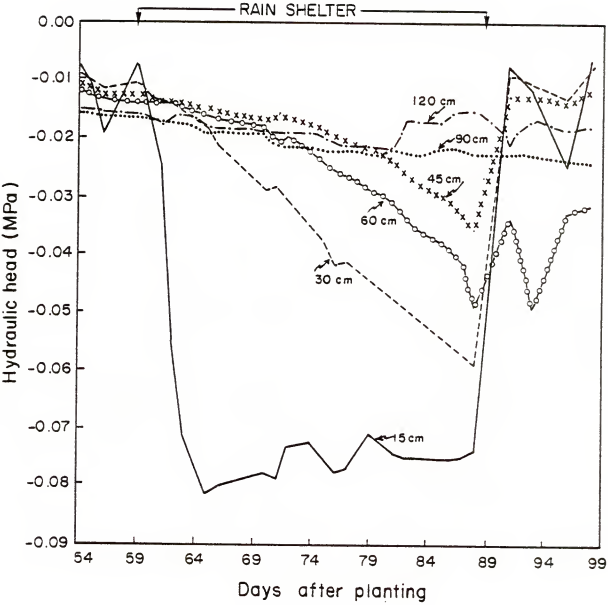

Fig. 1. Hydraulic head for induced-drought treatment of Pearl Early Runner peanuts.

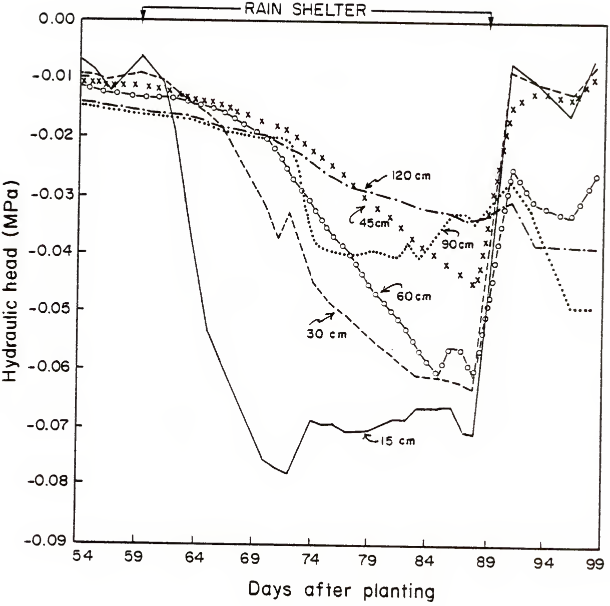

Fig. 2. Hydraulic head for induced-drought treatment of PI 383426 peanuts.

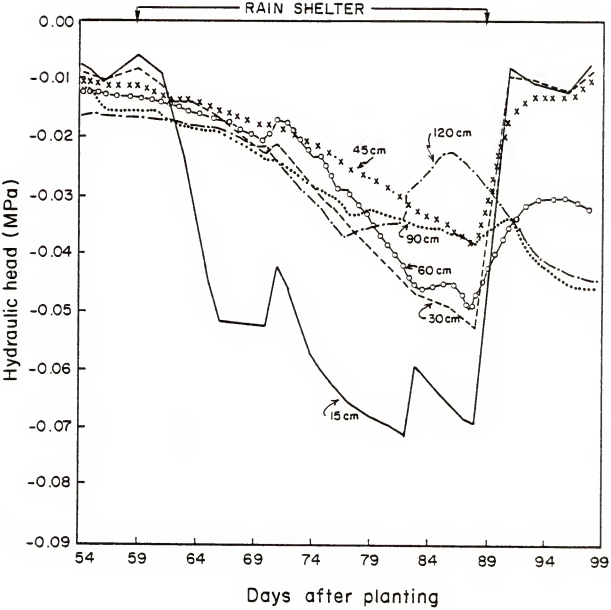

Fig. 3. Hydraulic head for induced-drought treatment of Early Bunch peanuts.

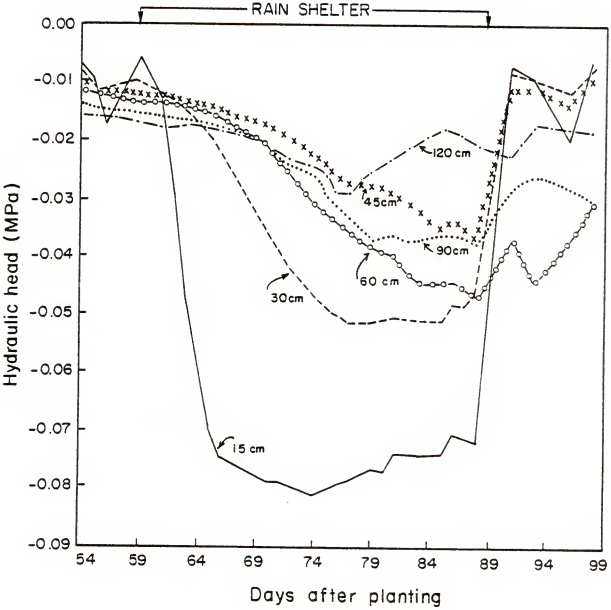

Fig. 4. Hydraulic head for induced-drought treatment of Florunner peanuts.

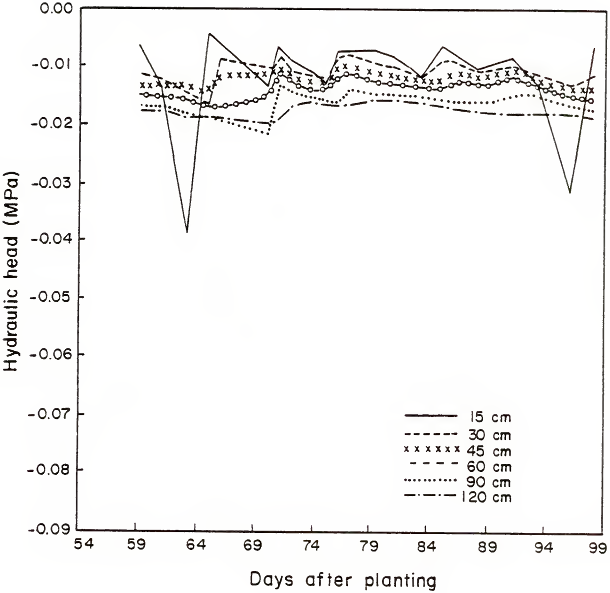

Fig. 5. Hydraulic head for irrigated treatment of Florunner peanuts.

and 120 cm depths throughout the drying cycle, Pearl Early Runner showed wilting symptoms earlier than the other cultivars, and, apparently was unable to absorb water at such depths (Fig. 1). By contrast, the other three genotypes showed deeper patterns of water extraction especially from the 60, 90, and 120 cm depths (Figs. 2, 3, and 4). A depletion of water at deeper layers of the soil can explain their better canopy growth when subjected to lack of rain and irrigation.

It was observed that water extraction at 60 cm depth (Figs. 1, 2, 3, and 4) started earlier and caused lower values of hydraulic head than at 45 cm depth. This may have been due to a hard pan which caused less water extraction in the region 30 to 45 cm of the soil profile.

It is necessary to emphasize that on two dates (70 and 75 DAP) heavy rains occurred at the experiment site, which caused some infiltration and lateral flow of water into the dry plots. These facts could be noticed from the tensiometer readings and helps explain the temporary increase in the hydraulic head, for example, in Fig. 3 at 15 cm and 71 DAP.

Figure 5 illustrates that the hydraulic head in the irrigated plots was fairly constant throughout the drying cycle, and that only the 15 cm profile exhibited some variation, which is expected during periods of high evaporative demand interspersed by irrigation and rainfall. The plants on the irrigated plots were not limited by soil water availability.

Stomatal Diffusive Resistance

The stomatal diffusive resistance at midday (Fig. 6) was low and nearly constant for the Pearl Early Runner plants in the irrigated plots, indicating that the stomata were wide open at midday. In contrast, the plants subjected to water withholding had higher and variable values of diffusive resistance beginning on day 64. The leaf resistance recovered rapidly after watering (89 DAP) as reported by Pallas et al. (1979). Although the mean values of diffusive resistance of Pearl Early Runner leaves in the dry treatment were higher than those in the wet treatment throughout the drying cycle, significant differences (P = 0.05) were found only at 64, 74, and 86 days after planting (Appendix Table 12). The reason for less frequent occurrence of significance is because a more conservative test was used and error only from treatment vs replicate and replicate was used to test treatment effect within a genotype. The subsamples were averaged to give mean values per treatment-replicate-genotype combination. More frequent occurrence of significance would occur if subsamples were considered the basic experimental unit.

The stomatal diffusive resistance at midday for PI 383426, Early Bunch, and Florunner (Figs. 7, 8, and 9) remained low during most of the drying cycle. Differences between the two irrigation treatments were found only after day 78 within these three genotypes. The values of stomatal diffusive resistance for PI 383426, Early Bunch, and Florunner under the two irrigation treatments were statistically equal (P = 0.05) throughout the drying cycle (Appendix Table 12). It is evident that these three genotypes had a longer equivalent time than

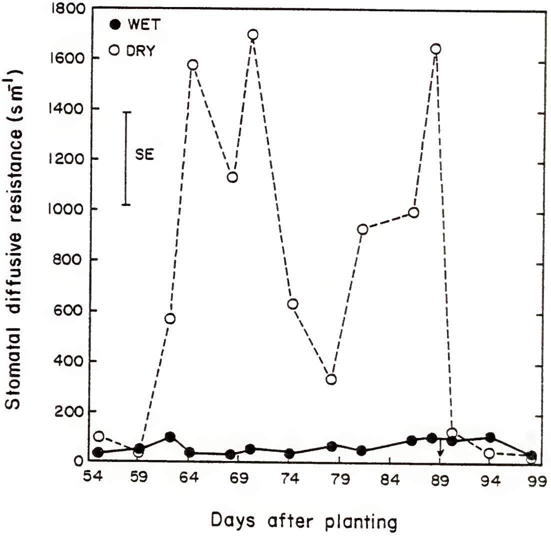

Fig. 6. Stomatal diffusive resistance at midday for induced-drought and irrigated Pearl Early Runner peanuts. Arrow on X-axis indicates rewatering. SE represents average standard error of the mean.

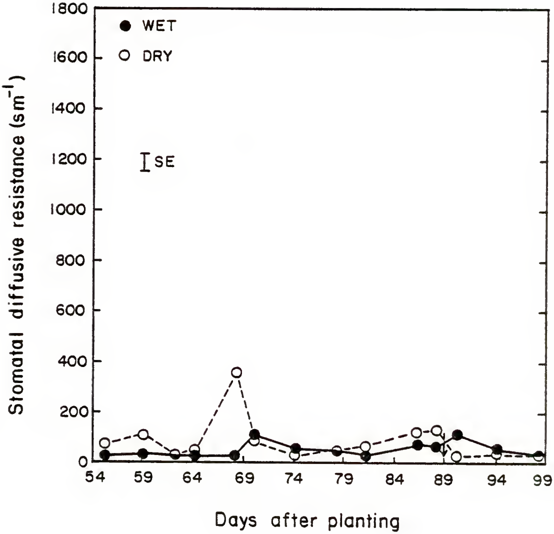

Fig. 7. Stomatal diffusive resistance at midday for induced-drought and irrigated PI 383426 peanuts. Arrow on X-axis indicates rewatering. SE represents average standard error of the mean.

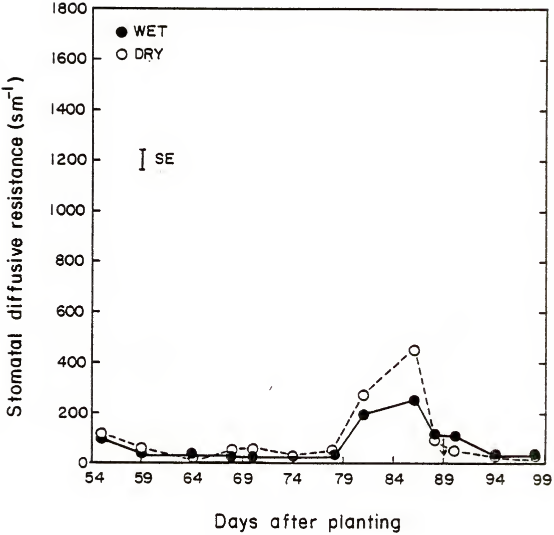

Fig. 8. Stomatal diffusive resistance at midday for induced-drought and irrigated Early Bunch peanuts. Arrow on X-axis indicates rewatering. SE represents average standard error of the mean.

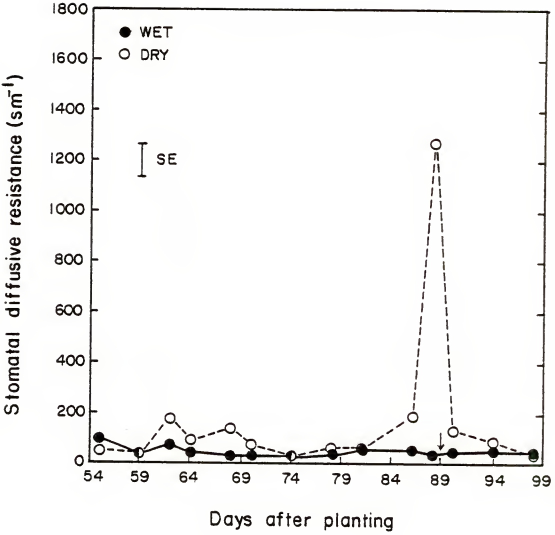

Fig. 9. Stomatal diffusive resistance at midday for induced-drought and irrigated Florunner peanuts. Arrow on X-axis indicates rewatering. SE represents average standard error of the mean.

Pearl Early Runner during which they did not suffer lack of moisture and therefore maintained open stomata. The magnitude of the values of diffusive resistance found for these genotypes in both treatments was comparable with those reported for Florunner peanuts by Allen et al. (1976).

Leaf Water Potential Components

Leaf water and osmotic potential of Pearl Early Runner peanuts subjected to drought showed lower values than the irrigated plants beginning at day 62 during the drying cycle. It was also observed that there was a time series trend in osmotic potential in both irrigation treatments. This decrease in osmotic potential seems to be induced by plant switchover from vegetative to reproductive growth. This trend of progressive decrease in osmotic potentials during the season has also been observed for soybeans (Ahmed, 1983). Like the water and osmotic potentials, leaf turgor potential (Fig. 10) of Pearl Early Runner peanut subjected to drought showed much lower values than the irrigated plants. The effect on turgor was highly associated with visible wilting symptoms in the field.

The other three genotypes (Figs. 11, 12, and 13) had higher values of water and turgor potentials than those recorded for Pearl Early Runner. The water potential components in these genotypes showed variability during the drying cycle, but there was no trend of lower values in the induced-drought treatment (Appendix Table 12).

Comparing Fig. 6 to Fig. 10, it is apparent that at the point where diffusive resistance started to increase, leaf water and turgor

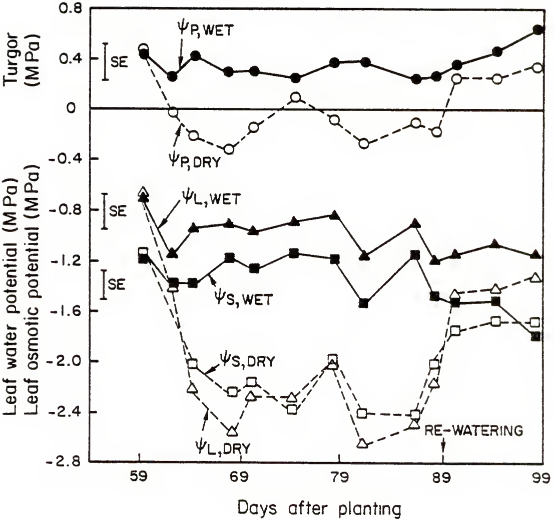

Fig. 10. Time course of leaf water potential (ψL), osmotic potential (ψs), and turgor potential (ψp) at midday for induced-drought and irrigated Pearl Early Runner peanuts. SE represents average standard error of the mean.

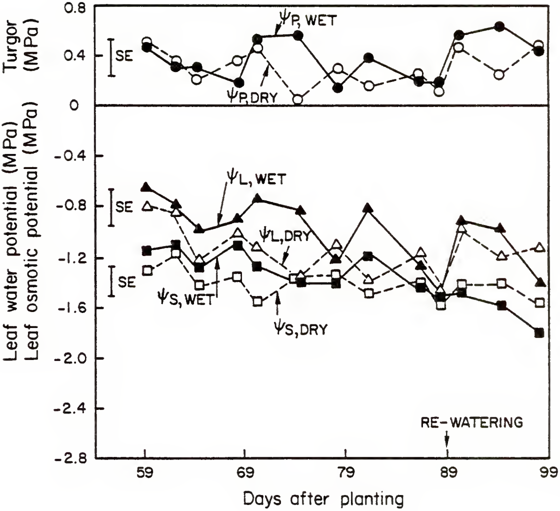

Fig. 11. Time course of leaf water potential (ψL), osmotic potential (ψs), and turgor potential (ψp) at midday for induced-drought and irrigated PI 383426 peanuts. SE represents average standard error of the mean.

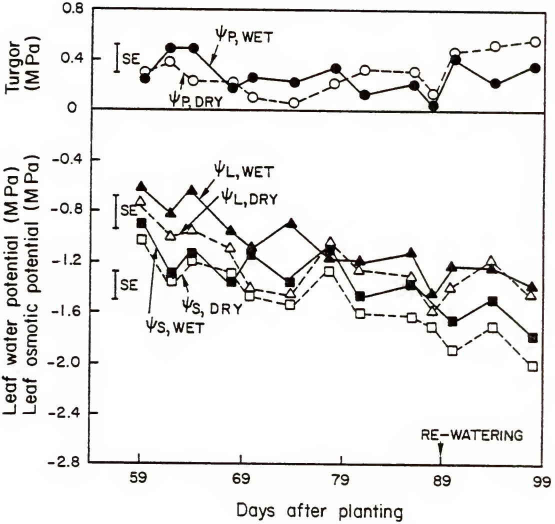

Fig. 12. Time course of leaf water potential (ψL), osmotic potential (ψs), and turgor potential (ψp) at midday for induced-drought and irrigated Early Bunch peanuts. SE represents average standard error of the mean.

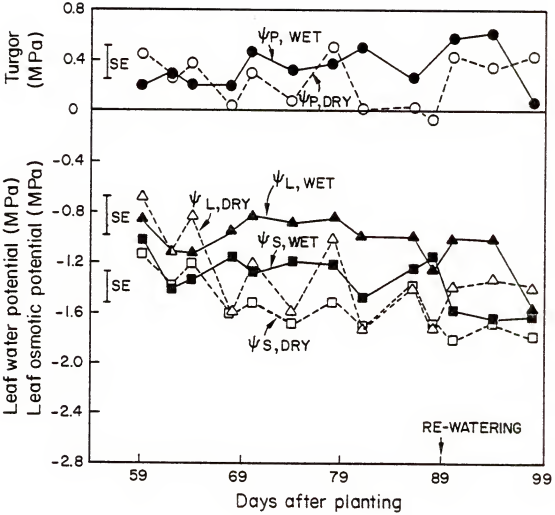

Fig. 13. Time course of leaf water potential (ψL), osmotic potential (ψs), and turgor potential (ψp) at midday for induced-drought and irrigated Florunner peanuts. SE represents average standard error of the mean.

potentials began to decrease. This suggests that due to the lack of turgor pressure, the stomata started to close.

Leaf Area Growth and Stem Elongation

Figure 14 shows the elongation of cotyledonary branches of the four genotypes under two irrigation treatments. Water stress reduced the growth of branches in all genotypes. However, the elongation of Pearl Early Runner branches was reduced by water stress earlier than the other genotypes and an appreciable decrease was already evident at 66 DAP, 8 days after watering was suspended. Rates of cotyledonary branch elongation of Pearl Early Runner (Fig. 15) were decreased by the water deficit much more than in the other genotypes (Appendix Table 13). Leaf area expansion on the cotyledonary branch (Fig. 16) was also reduced by water deficit in all genotypes, but once more, Pearl Early Runner was the most affected, indicating its greater susceptibility to water stress. This genotype had the greatest leaf area expansion with irrigation and the least when subjected to water stress. Figure 17 illustrates the reduction on its rate of leaf area expansion caused by the water stress. Leaf area expansion of Early Bunch (Fig. 16 and Table 14) apparently was the least affected by the water deficits and this can be correlated with its pattern of water extraction at deeper soil layers. It was also observed that Early Bunch was the earliest to decrease leaf area growth in both treatments. This may have been due to the fact that this genotype was the first to switch from vegetative to reproductive growth. The reduction in leaf expansion and stem growth of peanut plants under

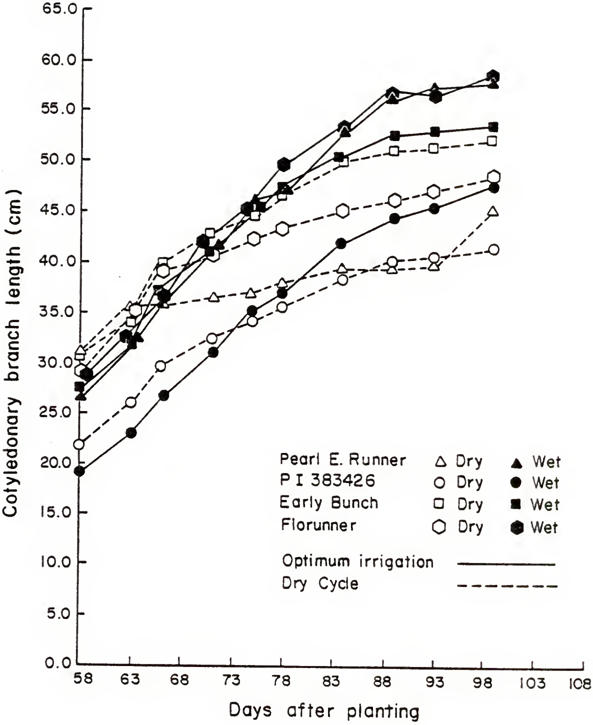

Fig. 14. Growth of cotyledonary branches of four peanut genotypes for induced-drought or irrigated conditions.

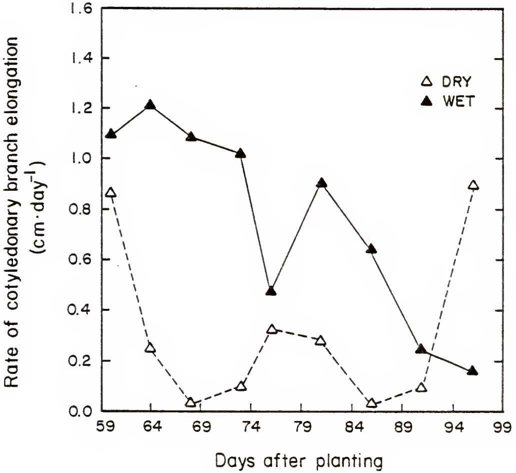

Fig. 15. Rate of cotyledonary branch elongation of Pearl Early Runner for induced-drought or irrigated conditions.

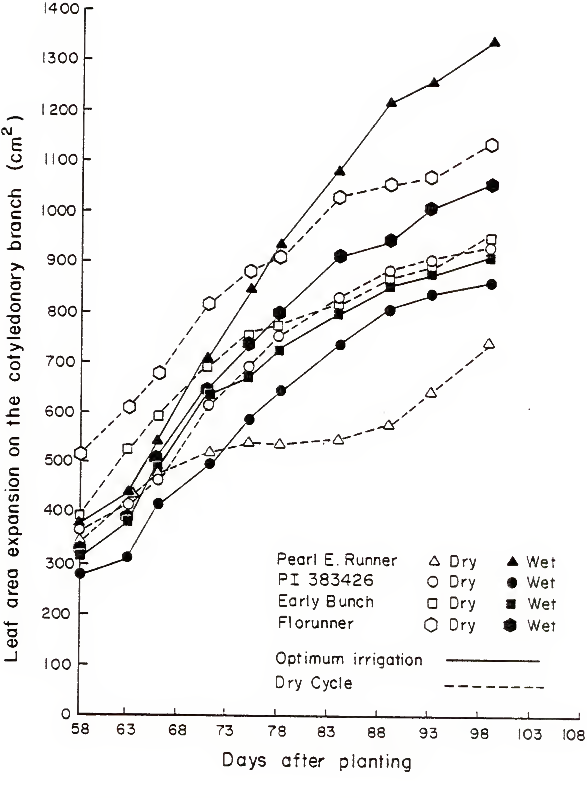

Fig. 16. Leaf area expansion on the cotyledonary branch of four peanut genotypes for induced-drought or irrigated conditions.

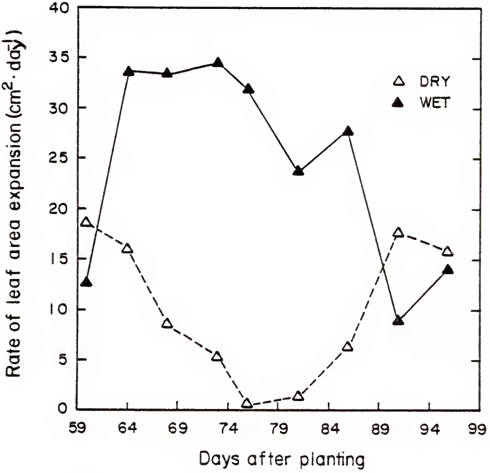

Fig. 17. Rate of leaf area expansion of Pearl Early Runner peanut for induced-drought or irrigated conditions.

water deficits have already been reported in the literature (Allen et al., 1976; Vivekanandan and Gunasena, 1976). The actual values of the length of the cotyledonary branch and its secondary branches is shown in Appendix Tables 15, 16, 17, and 18.

Light Interception

The light interception by the canopies of Pearl Early Runner and PI 383426 at 65, 72, and 79 DAP (Fig. 18) was affected by water stress, but stressed canopies attained almost the control values at 99 DAP, 10 days after irrigation was resumed on the drying plots. The light interception by the canopies of Early Bunch and Florunner peanuts was almost equal between treatments throughout the drying cycle.

Root Length Density

Peanut root length density at 64 DAP (Fig. 19) for Pearl Early Runner was less than the other genotypes, mainly below 60 cm. Florunner had the highest values of root length density at 15 and 30 cm in both treatments.

The values of root length density at 89 DAP are shown in Fig. 20. Apparently, Pearl Early Runner was the most affected by the water stress. This was evident from failure of its roots to proliferate throughout the lower soil profile under drying conditions. The root length density of the other three genotypes was not diminished by drying soil (presence of shelters), and in many cases the root density of Florunner and Early Bunch was higher in the stressed plots than in the controls. Reduced root length density at deeper depths for Pearl

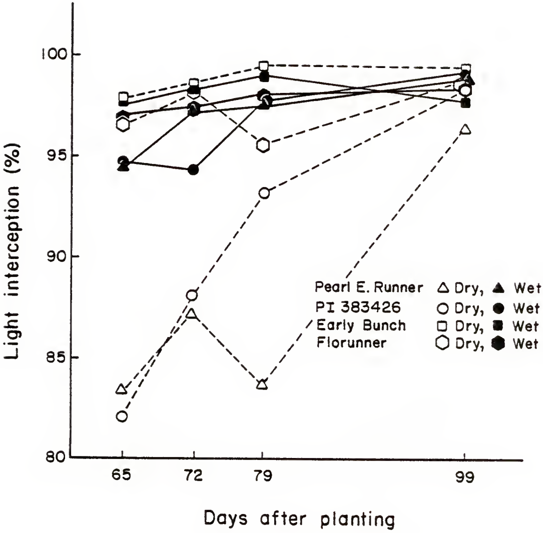

Fig. 18. Light interception at midday by the canopy of four peanut genotypes under two irrigation treatments.

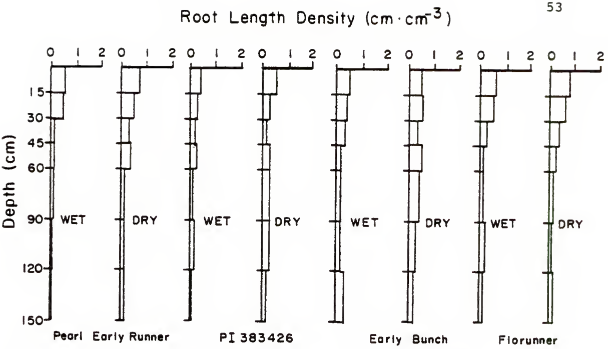

Fig. 19. Distribution of roots of four peanut genotypes at the beginning of the drying cycle (64 DAP) for two irrigation treatments.

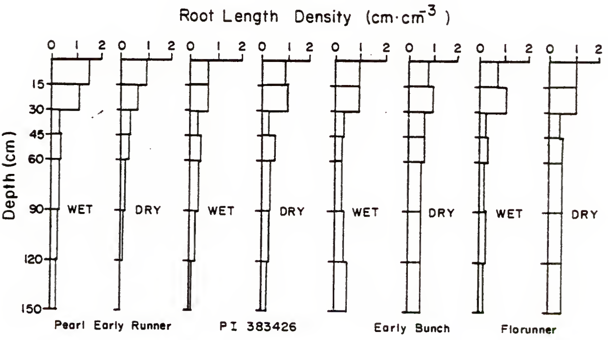

Fig. 20. Distribution of roots of four peanut genotypes at the end of the drying cycle (89 DAP) for two irrigation treatments.

Early Runner under drying conditions is consistent with its poorer water extraction, early wilting, lower turgor, reduced branch growth, and stomatal closure.

It was observed that root length density values were, in many cases, smaller in the 30 to 45 cm soil layer than above and below (Figs. 19 and 20), possibly due to a tillage pan which created a physical barrier for root growth. The presence of this hard pan in this soil was suspected from the results presented in Figures 1, 2, 3, and 4 and has been reported in the literature (Robertson et al., 1979; Robertson et al., 1980).

Relationships

This portion presents correlations between water relations parameters; namely, leaf water potential, osmotic potential, turgor potential, stomatal diffusive resistance and hydraulic head during the drying cycle.

The Relationship Between Turgor Potential and Leaf Water Potential

The relationship of turgor potential to leaf water potential in Pearl Early Runner, PI 383426, Early Bunch, and Florunner peanut leaves under two irrigation treatments is presented in Fig. 21. A linear decrease in ψp versus $\psi 1$ was observed in all genotypes, and from the equation presented in Fig. 21, negative values of ψp can be calculated as $\psi 1$ decreases below -2.0 MPa. These negative values of ψp almost certainly represent zero turgor and appeared as a result of dilution of the osmotic cell sap by extracellular water after freezing and thawing of the tissue (Boyer and Potter, 1973; Bennett et al.,

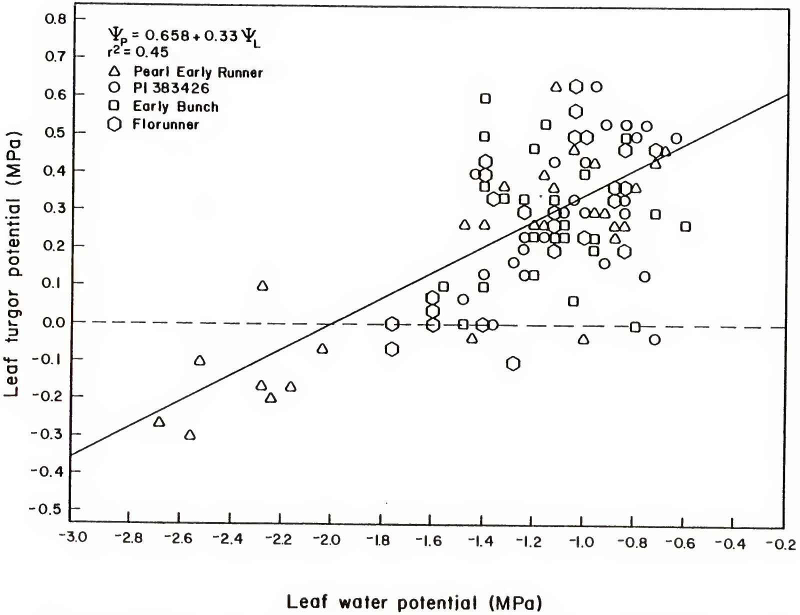

Fig. 21. The relationship of leaf turgor potential to leaf water potential of four peanut genotypes.

1981). The results of the regression analysis within genotype are presented in Table 1.

The Relationship Between Osmotic Potential and Leaf Water Potential

The relationship between osmotic potential and leaf water potential, for all genotypes, showed a linear correlation (Fig. 22). A decrease in ψl due to water stress was accompanied by a decrease in ψs. It is easily perceived that Pearl Early Runner attained the lowest values of osmotic and water potentials in response to the drying cycle.

The lowering of osmotic potential is an important physiological mechanism in adaptation of plants to water stress. Any loss of water from cells concentrates the solution within the cells and causes a decrease in osmotic potential (ψs). However, in addition to the decrease in ψs due to solute concentration, water deficits may also induce a net solute increase via osmotic adjustment (Kramer, 1983). If the net solute increase matches the decrease in ψl, then turgor pressure will be maintained, and as a consequence, physiological processes that are turgor-dependent will continue as ψl decreases (Levitt, 1980).

All genotypes had similar slopes of ψs versus ψl (Table 1) although the absolute decrease in ψs was greatest for Pearl Early Runner. The regression analysis, when all genotypes were combined, gave the following equation:

$\psi s = 0.661 + 0.67\ \psi l$ and a correlation of $r^2 = 0.77$.

Table 1. The relationship between leaf water potential components and stomatal diffusive resistance for four peanut genotypes.†

Pearl Early Runner	PI 383426	Early Bunch	Florunner
$\psi_s=-0.67+0.66\psi_L$	$\psi_s=-0.64+0.68\psi_L$	$\psi_s=-0.38+0.91\psi_L$	$\psi_s=-0.81+0.55\psi_L$
$\psi_p=0.67+0.34\psi_L$	$\psi_p=0.64+0.32\psi_L$	$\psi_p=0.37+0.08\psi_L$	$\psi_p=0.81+0.45\psi_L$
$DR=-341-285\psi_L+132\psi^2_L$	$DR=-86-285\psi_L-126\psi^2_L$	$DR=-245-530\psi_L-200\psi^2_L$	$DR=283+661\psi_L+409\psi^2_L$
$DR=588-2330\psi_p+2288\psi^2_p$	$DR=56+58\psi_p-64\psi^2_p$	$DR=72+251\psi_p-567\psi^2_p$	$DR=268-1067\psi_p+1164\psi^2_p$

†ψ_L, ψ_s, and ψ_p expressed in MPa; stomatal diffusive resistance in s m^{-1}.

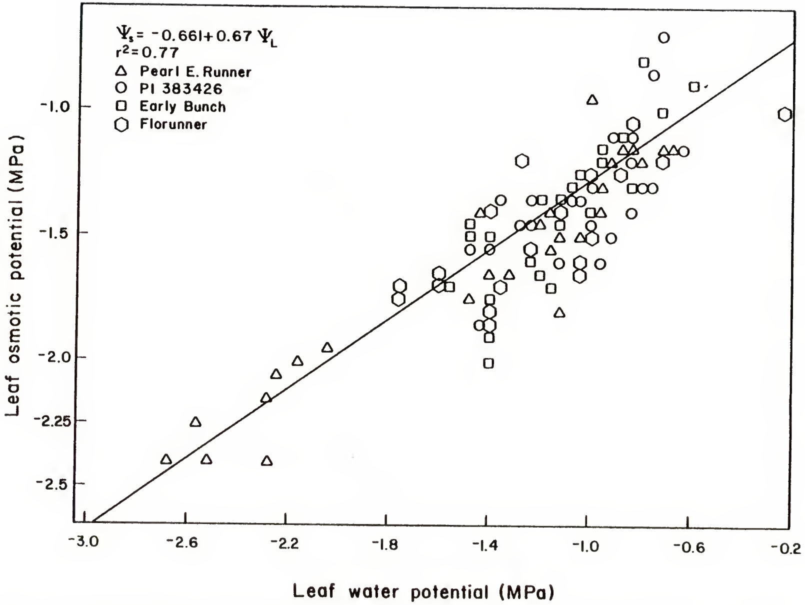

Fig. 22. The relationship of leaf osmotic potential to leaf water potential of four peanut genotypes.

Comparing slopes of ψp and ψs versus ψL (Figs. 21 and 22) illustrates that one-third of the decrease in total water potential is associated with a decline in ψp while two-thirds is a decline in ψs.

The Relationship Between Stomatal Diffusive Resistance and Leaf Water Potential

Figure 23 shows the relationship of stomatal diffusive resistance to leaf water potential when the four genotypes were analyzed together. There is a quadratic relationship between these two parameters, and a water-deficit-induced reduction in water potential is followed by an increase in stomatal diffusive resistance. Considering that stomata are the ports not only for water vapor loss but also for CO_2 uptake it is evident from Fig. 23 that water stress will reduce dry matter production by the peanut plants, and in this case the most significant reduction would occur within Pearl Early Runner plants. The results of the regression analysis within genotype are presented in Table 1.

The Relationship Between Stomatal Diffusive Resistance and Leaf Turgor Potential

Turgor pressure is important with respect to guard cell movements, and in Fig. 24 it is clear that when Pearl Early Runner plants were water stressed its leaves approached the lowest values of turgor pressure and consequently very high values of stomatal diffusive resistance. The other three genotypes presented higher values of turgor and lower values of diffusive resistance. The regression equation presented in Fig. 24 is valid within the range of -0.5 MPa to +0.4 MPa.

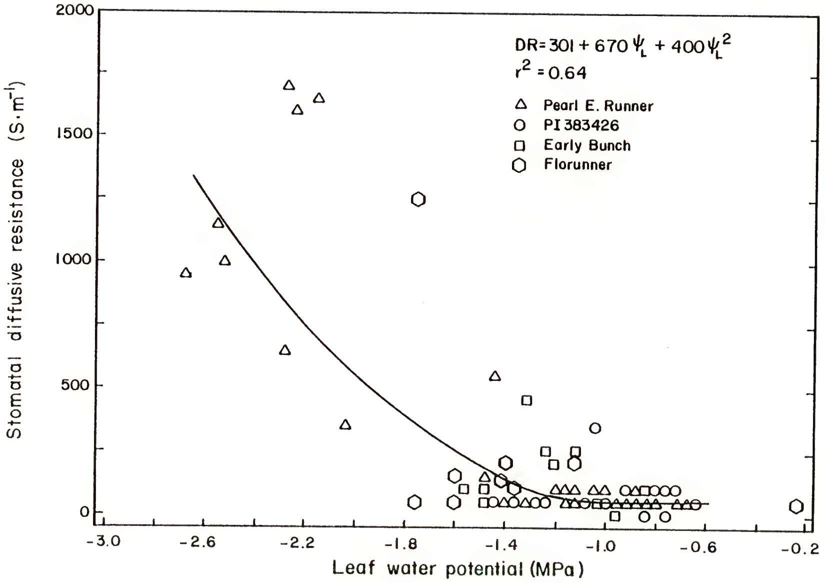

Fig. 23. The relationship of stomatal diffusive resistance to leaf water potential of four peanut genotypes.

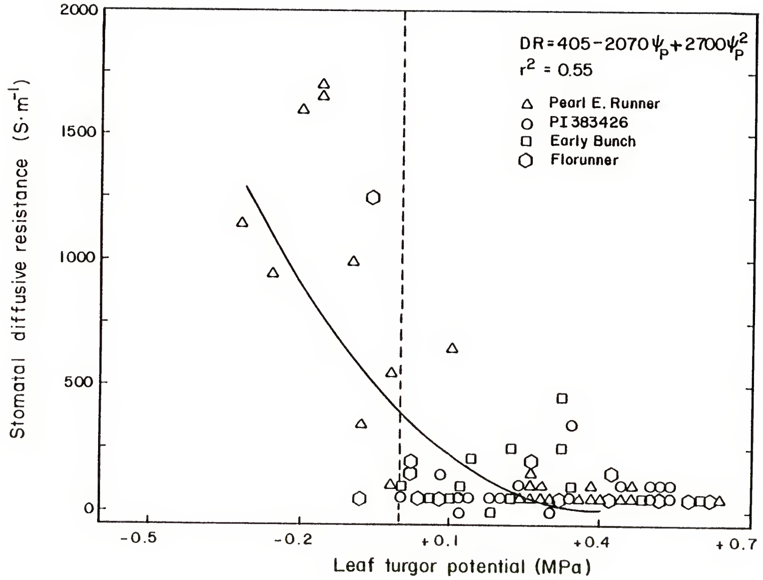

Fig. 24. The relationship of stomatal diffusive resistance to leaf turgor potential of four peanut genotypes.

The Relationships of Leaf Water Potential and Leaf Turgor Potential to Average Hydraulic Head

The relationship of leaf water potential to the average hydraulic head is presented in Fig. 25. The average hydraulic head was calculated with the data recorded for the tensiometers installed at 15, 30, 45, 60, 90, and 120 cm depths. It is worthwhile to mention that these average values consist of an approximation of the actual average hydraulic head because many of the mercury tensiometers had their columns cavitated at about -0.8 MPa, and adjustments were only possible after watering was resumed.

An examination of Fig. 25 indicates that the behavior of leaf water potential in response to the variation in the average hydraulic head was different among the genotypes. Indeed, Pearl Early Runner showed a completely different pattern in terms of this relationship, and when the average hydraulic head decreased below -0.025 MPa, the plants had their leaf water potential below-2.0 MPa. The minimum mean value of leaf water potential recorded for Pearl Early Runner was -2.66 MPa, while it was -1.48, -1.57, and -1.75 MPa for PI 383426, Early Bunch, and Florunner, respectively. The data for Pearl Early Runner illustrates a nicely consistent decline in ψL as hydraulic head declined. This was not as evident for the other three cultivars which suggests that their deeper roots were highly effective at extracting water from the deepest profile which was above a clay layer in the soil.

The same situation prevailed for ψp versus hydraulic head (Fig. 26) in which Pearl Early Runner was the only genotype to decrease in ψp as hydraulic head decreased.

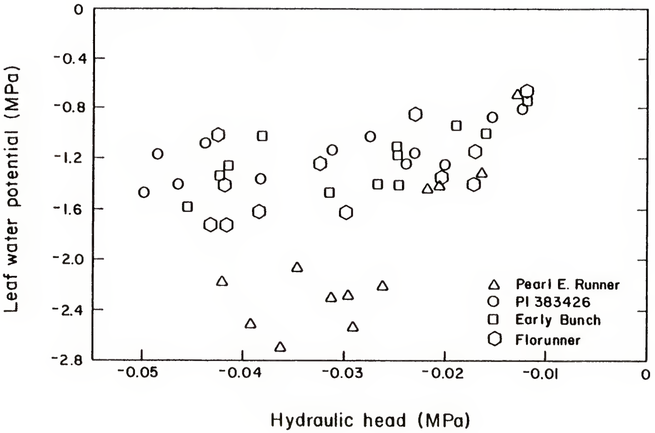

Fig. 25. The relationship between leaf water potential and hydraulic head of four peanut genotypes under water stress.

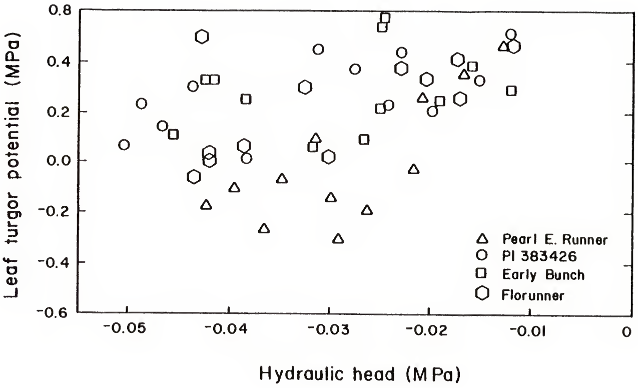

Fig. 26. The relationship between turgor potential and hydraulic head of four peanut genotypes under water stress.

The narrowest range of leaf water potential values in response to the variation in the hydraulic head was observed in the PI 383426 genotype (Fig. 25). This is an interesting fact and can be related to the ability of this genotype to fold the leaflets in response to water deficits. PI 383426 was the first genotype to show leaflet folding in the field, which occurred about 77 days after planting. This genotype was also the most erect plant and had less ground cover.

The relationship of leaf turgor potential to the average hydraulic head is presented in Fig. 26. With the exception of Pearl Early Runner, the genotypes responded similarly with respect to the turgor potential, and they showed only a slight tendency of lower values of ψp as the average hydraulic head decreased. Among the genotypes, only Pearl Early Runner and Florunner attained negative mean values of turgor potential. Although the interpretation of negative values of turgor is controversial (Tyree, 1976), the data may indicate relative values of turgor.

The development of water deficit in Pearl Early Runner started by showing symptoms of midday deficits. Kramer (1983) states that by midday on a hot sunny day, leaves lose their turgor, and leaf water potential is so low that most of water used in transpiration is concurrently entering through the roots. In the afternoon, as the stomata begin to close, the water loss decreases and absorption continues until the water potential rises to normal values. The development of long-term water deficits in plants begins slowly with a daily cycle, and continues until the plants are unable to recover at night after plants have depleted most of the soil water. This process happened with Pearl Early Runner, but not with the other genotypes, mainly because they started to extract water from deeper zones of the soil profile while Pearl Early Runner roots were apparently unable to explore deeper layers after the water in the first 60 cm was depleted.

Yield Data

Although pod yields of the four genotypes under study showed trends for lower yields when stressed (Table 2), only Pearl Early Runner showed a significant difference in production due to drought. The comparison of genotypes within irrigation treatments showed that under optimum irrigation Florunner had the highest pod yield, Early Bunch and Pearl Early Runner had similar yields and PI 383426 yielded the least. PI 383426 appears to lack yield capability or ability to respond to irrigation. When the plants were subjected to water withholding during peg elongation and pod formation there was no significant difference in pod yield between Florunner and Early Bunch. The pod production of Pearl Early Runner was reduced about 43% by the water stress and was statistically equal to the pod yield of PI 383426.

Since Pearl Early Runner showed several symptoms of water deficits such as wilting, stomata closure at midday, reduced foliage growth and shedding of leaves, the yield reduction appeared to be a logical consequence. The diminished pod production is a reflection of lower dry matter production, and obviously of the direct effect of water deficit on peg elongation, penetration and further development. The other three genotypes suffered to some extent from the water

Table 2. Pod yield of four peanut genotypes under two irrigation treatments.

Genotype	Optimum irrigation	Drought cycle
	kg ha^{-1}	
Pearl Early Runner	5398 B†a‡	3095 B b
PI 383426	3973 C a	3530 B a
Early Bunch	5299 B a	5032 A a
Florunner	6410 A a	5428 A a

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†Values in the same column with a capital letter in common do not differ significantly at the 5% level of probability using Duncan's Multiple Range Test.

‡Values in the same line with a lower case letter in common do not differ significantly at the 5% level of probability using Duncan's Multiple Range Test.

stress and had their pod yield decreased by 11, 5, and 15% for PI 383426, Early Bunch, and Florunner, respectively. Yield reductions of the other three genotypes suggested more stress than that suggested by the water relations and stomatal diffusive resistance measurements. Possibly, turgor reductions were more effective in reducing growth and fruiting than on stomatal activity. This differential sensitivity of cellular processes to water stress agrees with the suggestions of Hsiao (1973).

Similar trends among the genotypes and irrigation treatments were found for seed yield (Table 2). All genotypes had their seed yield reduced by the water stress but significant differences were noticed only for Pearl Early Runner and Florunner.

Under optimum irrigation, Florunner had the highest seed yield, followed by Early Bunch and Pearl Early Runner which produced similar seed yield; the lowest yield occurred in PI 383426. This ranking was somewhat different under the drought cycle, and as happened with pod yield, the best producers were Florunner and Early Bunch followed by PI 383426 and Pearl Early Runner.

Water stress also caused a decrease in the shelling percentage of all genotypes (Table 3). Florunner had the highest shell-out percentage in both irrigation treatments. Under optimum irrigation there were no significant differences in shelling percentages among the other three genotypes. Under water stress, Pearl Early Runner had the lowest shelling percentage and PI 383426 and Early Bunch had similar values.

There was a significant difference in the weight of 100 seeds in the peanut genotypes. Under both irrigation treatments, the rank of

Table 3. Seed yield and quality of four peanut genotypes under two irrigation treatments.

Genotype	100-seed weight		Shelling percentage		Seed yield	
	Optimum irrigation	Dry cycle	Optimum irrigation	Dry cycle	Optimum irrigation	Dry cycle
	g		%		kg ha^{-1}	
Pearl Early Runner	55.02 C†a‡	50.33 Ca	75.0 Ba	70.2 Cb	4051 Ba	2178 Bb
PI 383426	51.46 Ca	47.84 Ca	75.3 Ba	71.8 Bb	2993 Ca	2536 Ba
Early Bunch	97.12 Aa	97.39 Aa	74.7 Ba	72.4 Bb	3965 Ba	3646 Aa
Florunner	62.82 Ba	54.54 Bb	77.9 Aa	75.1 Ab	5000 Aa	4081 Ab

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†Values in the same column with a capital letter in common do not differ significantly at the 5% level of probability using Duncan's Multiple Range Test.

‡Values in the same line with a lower case letter in common do not differ significantly at the 5% level of probability using Duncan's Multiple Range Test.

decreasing weight of 100 seeds was: Early Bunch, Florunner, and PI 383426 plus Pearl Early Runner. Florunner was the only genotype exhibiting statistically different 100-seed weights between the two irrigation treatments, although PI and Pearl Early Runner showed a trend for lower seed weights with water stress.

Root and Shoot Growth of Four Peanut Genotypes Grown in Acrylic Tubes Under Greenhouse Conditions

This section presents root and shoot growth characteristics of the four peanut genotypes grown for 61 days in acrylic tubes filled with a Kendrick fine sand.

Figure 27 shows that at 12 days after planting the taproot of the four genotypes was already 20 cm long and that the elongation process continued throughout the experiment. The differences among the genotypes were not very large initially but became increasingly apparent after 42 days after planting when the rate of taproot growth of Pearl Early Runner diminished more than those of the other three genotypes. The absolute values of taproot length for Early Bunch and Florunner were somewhat smaller than those reported by Ketring et al. (1982). The most plausible explanation for these differences is the type of substrate used to fill the tubes and also climatological factors such as light intensity and temperature. Ketring et al. (1982) used Perlite media in contrast to fine sand in this study. Temperatures in the glasshouse were set for 32/24°C day/night regimes in Ketring's experiment while in this study the air temperatures were cooler with a mean value of 22.7°C (Appendix Table 7).

Figure 27 suggests a constant rate of taproot extension for all genotypes from 12 to 51 days after planting. When the data up to 51

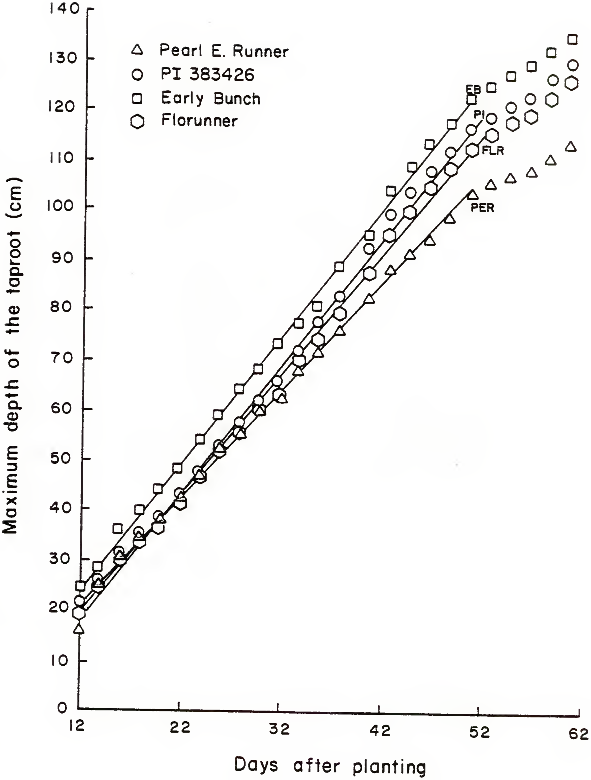

Fig. 27. Taproot growth of four peanut genotypes in acrylic tubes in the greenhouse.

days was subjected to regression analysis, slope values of 2.15, 2.47, 2.53, and 2.41 cm day^{-1} were observed for Pearl Early Runner, PI 383426, Early Bunch, and Florunner, respectively, and a test of slopes using GLM showed that Pearl Early Runner rates of taproot elongation were different from the other genotypes studied. The capability of peanut roots to grow deep in the soil profile has been stressed in the literature (Allen et al., 1976; Stansell et al., 1976; Robertson et al., 1980; Ketring et al., 1982).

The seasonal progression of peanut rooting depth estimated from soil water extraction profiles in the field showed rates of root elongation similar to the values found in this study, with slopes around 2.3 cm day^{-1} (Hammond, L. C., W. K. Robertson, K. J. Boote, L. H. Allen, Jr., and R. J. Varnell, unpublished data).

The progression of the vegetative growth stages is presented in Fig. 28. The determination of the vegetative growth stage was based on the number of developed nodes on the main axis of the peanut plant, beginning with the cotyledonary node as zero (Boote, 1982). The node is counted when its tetrafoliate leaf is unfolded and its leaflets are flat. The genotypes showed nearly similar rates of node development although the rate appeared slightly more rapid for Early Bunch. A linear relationship between number of developed nodes and days after planting was found for all genotypes under study with slopes of 0.18, 0.19, 0.21, and 0.18 nodes day^{-1} for Pearl Early Runner, PI 383426, Early Bunch, and Florunner, respectively (Fig. 28). When these slopes were subjected to GLM, it was found that Early Bunch and PI 383426 were different from Pearl Early Runner which was equal to Florunner.

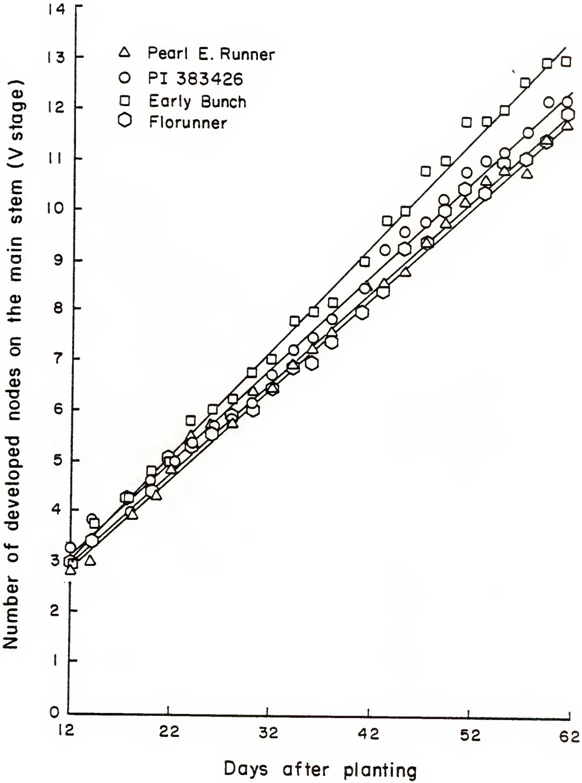

Fig. 28. Number of developed nodes on the main stem vs time for four peanut genotypes in the greenhouse.

By coincidence, or due to true genotypic association, the genotypes with higher rates of node expression had the greater rates of taproot elongation. The experimental period coincided with the period of rapid node development which begins to slow down progressively after 70 days as the plants mature and set fruits (Boote, 1982). Florunner and Pearl Early Runner achieved the beginning bloom (R1) stage at 43 DAP, Early Bunch at 47 DAP, and PI 383426 at 49 DAP.

The root dry weight values at various soil depths for the peanut genotypes are shown in Fig. 29. The four genotypes had the greatest root concentration in the surface 15 cm of soil. There were significant differences (P = 0.05) among the genotypes in root weight distribution at the various depths. Pearl Early Runner had the lowest values of root dry weight in all depths from 20 to 180 cm. Since Pearl Early Runner was the first genotype to show wilting symptoms under field conditions, this could be associated with its lower capacity for deep root growth, as observed for sorghum (Nour and Weibel, 1978; Jordan and Miller, 1980) and for rice (Hurd, 1968; Hurd, 1974).

Like root dry weight, root length density was greatest in the top 15 cm for all genotypes studied and almost always decreased as the depth increased (Fig. 30). The ranking of genotypes in order of decreasing root length density, in almost all depths below 20 cm, was as follows: Early Bunch, Florunner, PI 383426, and Pearl Early Runner. Pearl Early Runner had the most pyramidal rooting length profile, i.e., high rooting length in the top 15 cm and low rooting length density at deeper depths. These root length densities are

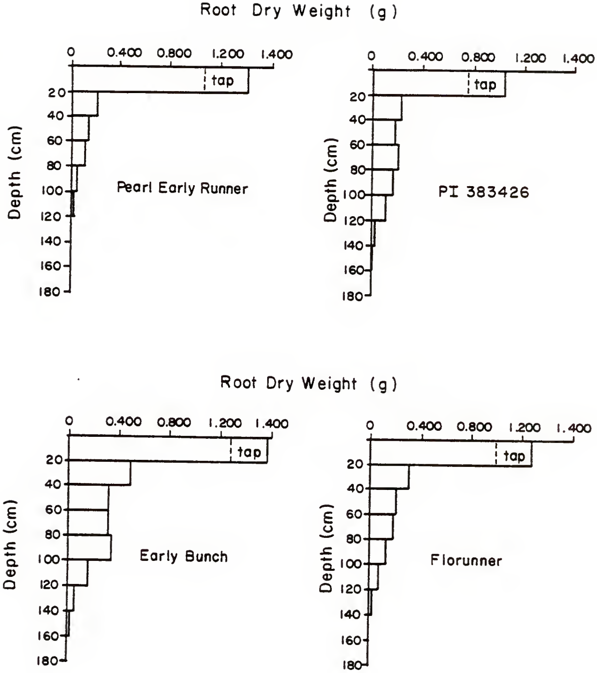

Fig. 29. Dry weight of roots vs depth of four peanut genotypes in the greenhouse.

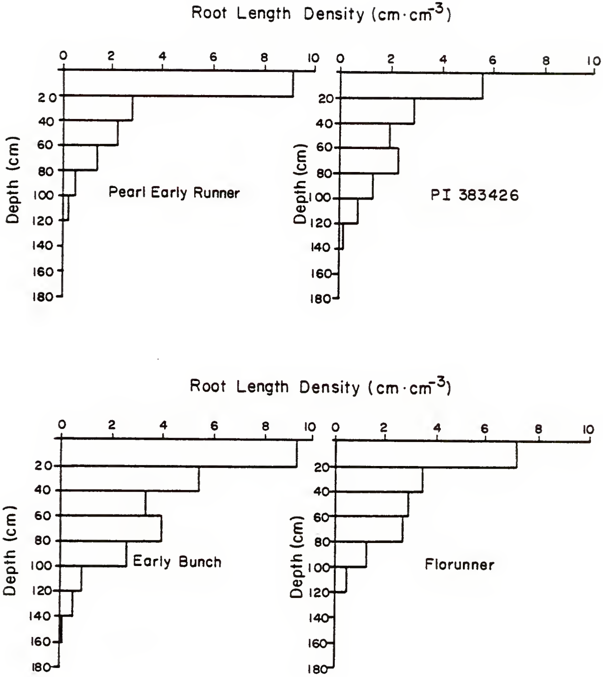

Fig. 30. Root length density vs depth of four peanut genotypes in the greenhouse.

about 10-fold greater than field values because the soil rooting volume was about one-fifth that for field plants.

The distribution of dry matter in plant organs at the end of the greenhouse experiment (61 days after planting) is presented in Table 4. Early Bunch had the highest value of root dry weight, and the other three genotypes had similar values. Dry weight of nodules was nearly comparable among the four genotypes, and only the nodule weights of Pearl Early Runner and PI 383426 were statistically different between each other.

PI 383426 had the lowest leaf dry weight, but was statistically equal to Florunner which was equal to Pearl Early Runner. Early Bunch had the highest leaf dry weight, but it was not different from Pearl Early Runner. The lowest stem dry weight was also found for plants of PI 383426 whereas the other three genotypes did not differ in stem dry weight.

The highest production of total dry matter was recorded for Early Bunch, but its production was statistically equal to the dry matter production of Pearl Early Runner. Dry matter production of Florunner was similar to that of Pearl Early Runner. Although the total plant dry weight of PI 383426 was the smallest of the four genotypes, it was statistically equal to Florunner.

Root:shoot ratio was calculated by dividing root dry weight by shoot dry weight (Fig. 31a). Differences were found among the genotypes, with Early Bunch having the highest ratio and Pearl Early Runner the lowest value; Florunner and PI 383426 did not differ significantly in their ratio of root biomass to aerial biomass. A

Table 4. Dry weight of plant parts of four peanut genotypes after 61 days of growth in acrylic tubes in greenhouse.

Genotype	Root	Nodule	Leaf	Stem	Total
	g plant^{-1}				
Pearl Early Runner	1.96 B†	0.27 A	6.16 AB	4.89 A	13.28 AB
PI 383426	1.94 B	0.17 B	4.70 C	3.18 B	9.99 C
Early Bunch	3.26 A	0.21 AB	6.90 A	4.87 A	15.24 A
Florunner	2.16 B	0.24 AB	5.30 BC	4.27 A	11.97 BC

†Values followed by the same letter within a column are not significantly different at the 5% level of probability on the Duncan's Multiple Range Test.

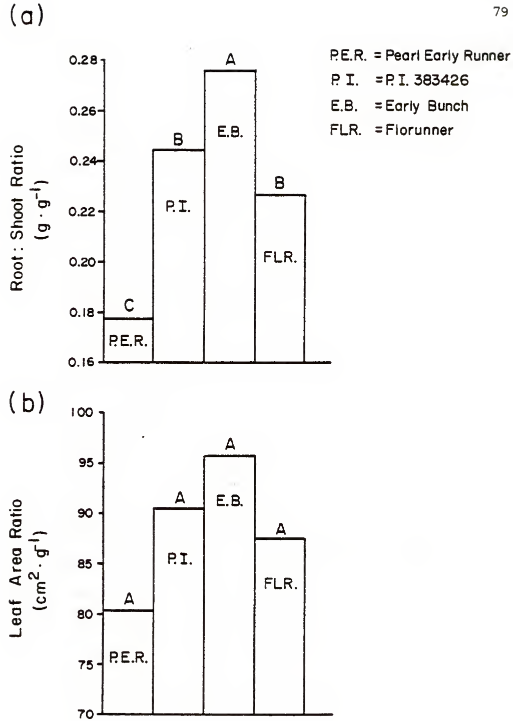

Fig. 31. Root:shoot ratio (a) and leaf area ratio (b) of four peanut genotypes in the greenhouse. Bars with the same letter on top are not significantly different at the 5% level of probability based on the Duncan's Multiple Range Test.

high root:shoot ratio may improve the adaptation of a water spender plant to drought because less water needs to be absorbed per unit root area to supply the shoot, and also because a plant with a larger root system will explore a larger volume of soil. Relatively poor allocation of assimilate to root growth is again consistent with the wilt susceptibility of Pearl Early Runner.

Figure 31b shows the behavior of the leaf area ratio, which is the total leaf area divided by total weight of the plant. The trend here is the same as that observed for root:shoot ratio (Fig. 31a) although there were no significant differences in leaf area ratio among the genotypes.

The leaf area to root weight ratio (Fig. 32a) was highest for Pearl Early Runner, followed by Florunner, PI 383426, and Early Bunch. Pearl Early Runner showed proportionally more leaf area per unit of root weight but was statistically equal to Florunner which was not significantly different from PI 383426 and Early Bunch.

The ratio between leaf area and total root length is shown in Fig. 32b. Early Bunch showed proportionally less leaf area per unit of root weight and Pearl Early Runner had the highest ratio, but there were no signficant differences among the genotypes. A plant with a higher ratio of leaf area to root weight or length would be expected to be the first to wilt if soil water became limiting.

These results in greenhouse studies would suggest that Pearl Early Runner invests more assimilate into shoot weight and leaf area, but less into root weight, especially at deeper soil depths. This strategy would not be a problem if water is abundant, but would cause

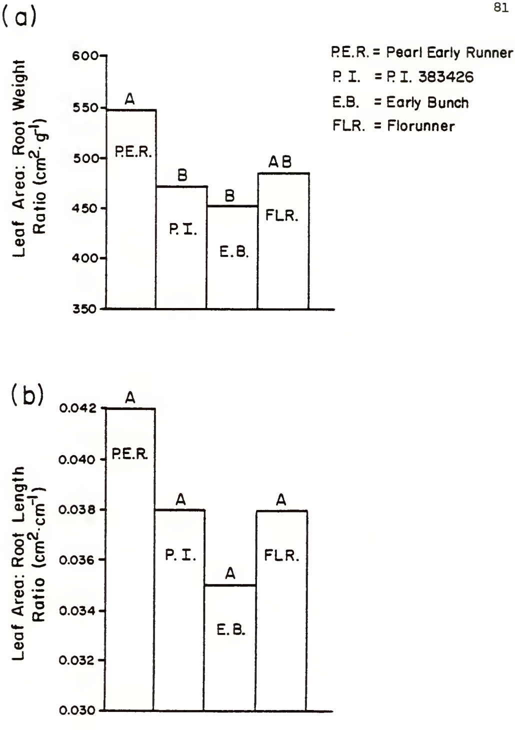

Fig. 32. Leaf area:root weight ratio (a) and leaf area:root length ratio (b) of four peanut genotypes in the greenhouse. Bars with the same letter on top are not significantly different at the 5% level of probability based on the Duncan's Multiple Range Test.

quick wilting as water became deficient. This scenario is consistent with the field observations and measurements.

SUMMARY AND CONCLUSIONS

Two experiments, one in the field and another in a greenhouse, were conducted with peanut (Arachis hypogaea L.) genotypes Pearl Early Runner, PI 383426, Early Bunch, and Florunner, to study their drought response and to relate the differential drought resistance to any differences in stomatal control, leaf water potential components, leaf area expansion, and growth of the root system of the four genotypes.

In the field, two irrigation treatments were imposed on the plants: optimum irrigation throughout the crop cycle, with irrigation applied when the hydraulic head at 15 cm reached -0.02 MPa, and optimum irrigation except during peg elongation and pod formation (between 59 and 88 days after planting) when mobile transparent shelters were used to exclude rainfall. Midday measurements of plant water-relations parameters were conducted every 2 to 5 days during the drying cycle. In addition, the following response data were obtained: leaf area expansion on the cotyledonary branch, rooting length density versus depth, light interception by the canopy, soil water status, and yield of the crop.

In the greenhouse experiment, the four peanut genotypes were planted in 2-m long acrylic tubes filled with soil collected from the field site and placed in wooden boxes inclined 15° from vertical. All tubes were irrigated with water and/or Hoagland's solution usually every other day as needed to maintain a good soil water environment for the roots. Root growth was measured by recording the tap root length every other day on the inclined interface of each tube. Shoot growth was measured at the same intervals by following the node progression on the main stem. At the end of the experiment (61 days after planting), the shoots were separated into stem and leaves, leaf area was measured, and dry weights of these plant parts were recorded. Additionally, the soil from the tubes was extracted in 20-cm cores and the roots were washed from the cores in order to obtain data on root length density and dry weight of roots and nodules at each tube depth.

From the field experiment the following conclusions can be drawn on the water relations, growth, and yield of the four peanut genotypes:

The hydraulic head in the well-irrigated treatment was fairly constant throughout the drying cycle and the plants were not limited by soil water availability. In contrast, the hydraulic head in the drying treatment reached much lower values, mainly in the 0 to 15 cm layer. There were differences among the genotypes in water extraction from the soil. PI 383426, Early Bunch, and Florunner showed deeper patterns of water extraction especially from 60, 90, and 120 cm depths, and Pearl Early Runner showed wilting symptoms earlier than the other genotypes, and apparently was unable to absorb sufficient water from deep zones of the soil profile.

The stomatal diffusive resistance at midday was low and nearly constant for Pearl Early Runner plants on the irrigated plots, and in both irrigation treatments for the other three genotypes. By contrast, the Pearl Early Runner plants subjected to water stress had higher values of diffusive resistance throughout the drying cycle.

Leaf water, osmotic, and turgor potential of Pearl Early Runner subjected to water deficit had lower values than the well-irrigated plants and the reduction in turgor potential was associated with visible wilting symptoms. PI 383426, Early Bunch, and Florunner did not show significantly lower values of water potential components in the induced-drought treatment.

Water stress reduced stem elongation and leaf area growth of the cotyledonary branch in all genotypes but Pearl Early Runner was the most affected.

Since water stress affected shoot growth, it was expected that light interception by the peanut canopies would also be affected; this fact was evident mainly in the Pearl Early Runner plots. The canopies recovered rapidly after irrigation and light interception attained almost the control values, 10 days after irrigation was resumed.

Root length density at 64 DAP for Pearl Early Runner was less than the other three genotypes, especially below 60 cm. The values of root density obtained at 89 DAP showed that growth of Pearl Early Runner roots was reduced by the water stress.

The relationships between leaf water potential components and stomatal diffusive resistance illustrated that stomatal response to internal leaf water status was no different in the wilt susceptible genotype than in the other genotypes. This seems to reinforce the idea that differences were caused by differential root extraction of water from the soil.

Pod and seed yields of the four genotypes under study were reduced by water stress but the differences were not always significant. The wilt susceptible genotype had the largest yield reduction in response to water stress. The decrease in pod yield of PI 383426, Early Bunch, and Florunner suggested more stress than that observed from water relations and diffusive resistance measurements. This fact suggests that the decrease in turgor was more effective in reducing growth and fruiting than on stomatal activity. Water stress also caused a decrease in the shelling percentage of all genotypes.

The results obtained in the greenhouse allow the following conclusions on root and shoot growth of the four peanut genotypes studied:

The differences in taproot elongation among the genotypes were not very large initially but became more apparent with time after planting when the rate of root growth of Pearl Early Runner decreased more than those of the other three genotypes.

A linear relationship was found between number of developed nodes on the main stem and days after planting. There were differences among the genotypes in rate of node development; Early Bunch and PI 383426 were different from Pearl Early Runner which was equal to Florunner.

There were significant differences among the genotypes in root weight distribution at the various depths. Pearl Early Runner had the lowest root dry weights in all depths from 20 to 180 cm. Like root dry weight, root length density values differed among the genotypes and the ranking of genotypes in order of decreasing root length density, in almost all depths below 20 cm, was as follows: Early Bunch, Florunner, PI 383426, and Pearl Early Runner. The total root dry weight was highest for Early Bunch, and the other genotypes presented similar values. Early Bunch also had the highest production of total dry matter.

The root:shoot ratio was highest for Early Bunch and lowest for Pearl Early Runner. The poor allocation of assimilate for root growth in Pearl Early Runner is consistent with its susceptibility to wilting.

Although there were differences in leaf area ratio, leaf area to root weight ratio, and leaf area to total root length ratio among the genotypes, the differences were not always statistically significant. Pearl Early Runner tended to have the highest values of leaf area to root weight ratio and of leaf area to root length ratio and the lowest value of leaf area ratio.

The greenhouse results suggest that the wilt suceptible genotype, Pearl Early Runner, allocates more assimilate to shoot growth but less to root growth, mainly at deeper soil depths. These results are consistent with the field measurements and since there were no differences in stomatal response to water potential components, the reduced root system of Pearl Early Runner at deeper depths is the cause of its poorer water absorption, lower turgor, early wilting, reduced canopy growth, and high stomatal diffusive resistance observed during the water stress cycle.

APPENDIX

Table 5. Irrigation schedule for the field experiment.

Date	Days after planting	Irrigation amount on each treatment: Optimum irrigation	Irrigation amount on each treatment: Drying cycle
		cm	cm
June 10	36	1.90	1.90
July 2	58	1.78	1.78
July 9	65	1.68	-
Aug 10	97	1.52	2.54
Sept 2	120	2.03	2.03
Total		8.91	8.25

Table 6. Climatological data for the field experiment.

May 1982

Day	Temperature (T) oF Air 5' Max.	 Min.	 Soil 10 cm depth* Max.	 Min	Rain Inches	Pan Evap. Inches	Wind M/da	%RH Min.	Solar Radiation PAR E/m2	 TOTAL MJ/m2
1	80	60	77	72		.16	65	45	36.3	18.2
2	82	59	77	72		.25	45	48	39.6	19.9
3	84	59	77	72		.13	34	40	43.2	21.8
4	84	55	77	72		.23	30	42	46.2	23.6
5	83	58	78	73		.30	49	32	47.0	24.4
6	82	54	77	73		.24	44	34	42.2	21.7
7	84	53	78	73		.14	50	34	45.8	23.6
8	85	64	77	74	.04	.22	69	34	35.9	18.2
9	85	59	80	74		.28	53	24	51.2	25.3
10	85	56	80	74		.29	47	30	50.3	26.3
11	86	52	81	72		.22	30	45	48.3	24.9
12	88	56	82	73		.25	30	35	46.3	23.5
13	87	56	82	75		.30	39	32	47.6	24.2
14	88	55	84	75		.33	41	40	52.5	26.7
15	90	60	83	76		.23	23	25	46.9	23.9
16	92	60	84	76		.25	18	24	44.7	22.8
17	91	60	83	77		.10	22	39	44.6	22.7
18	88	62	83	78		.29	34	42	42.7	21.5
19	87	62	82	77		.26	43	41	45.1	22.4
20	89	61	82	77		.22	39	38	45.7	22.5
21	90	61	82	78		.30	34	33	46.2	22.6
22	91	62	83	77	.08	.25	46	50	36.7	17.4
23	92	68	81	79	1.38	.36	53	50	27.0	13.2
24	91	66	83	76	.14	.17	23	58	43.9	21.5
25	91	68	84	78	.10	.18	29	54	42.1	20.3
26	89	69	85	79	.04	.20	28	70	31.5	15.0
27	90	70	87	79		.15	28	72	37.5	18.2
28	92	69	85	80	.17	.17	26	65	44.8	22.1
29	94	72	86	82		.26	27	59	39.5	19.3
30	90	73	85	82	.22	.12	28	64	15.7	7.0
31	86	69	80	78	.94	.09	25	90	24.7	11.8
May avg.										
1982	87.6	61.5	81.5	75.9	3.11	6.95	37.2	44.3	1291.7	647.5
1981	89.5	60.8	83.4	77.0	.83	9.03	55.8	34.1**	1421.8	713.6
70yr	87.4	63.6		(NORMAL)	3.54					

Accumulated Rainfall Summary (Inches)

From Jan 1982	27.46
From Jan 1981	11.61
From Jan Normal	17.3

NOTE: Observation time is 4:30 P.M.

*Under Centipede Sod

**25-day Average

Table 6.--continued.

June 1982

	Temperature (T) oF				Rain	Pan	Wind	%RH	Solar Radiation	
	Air 5'		Soil 10 cm depth*			Evap.			PAR***	TOTAL***
	Max.	Min.	Max.	Min	Inches	Inches	M/da	Min.	E/m2	MJ/m2
1	88	70	82	79	.60	.29	35	54	43.9	20.0
2	92	68	87	81		.17	30	53	53.5	24.9
3	92	73	84	82	.07	.25	31	58	34.4	15.8
4	92	72	86	81		.17	15	51	47.5	21.6
5	93	65	88	83		.29	26	51	51.6	23.8
6	94	65	89	84		.28	39	36	56.3	26.5
7	93	65	88	83		.27	20	44	57.2	26.9
8	94	63	88	82		.15	34	42	56.3	26.3
9	94	67	88	84		.36	35	37	51.8	24.4
10	94	70	88	83		.24	40	44	54.7	25.5
11	95	67	88	83		.42	67	48	51.1	23.6
12	88	68	88	82	2.00+	FLOOD	24	48	33.4	15.2
13	92	70	86	81		.22	21	54	N/A	N/A
14	92	65	87	83		.27	35	37	55.7	25.5
15	93	69	88	73		.26	16	52	51.3	23.2
16	93	72	88	84		.27	21	50	56.1	25.5
17	88	70	89	84	.32	.16	35	85	14.4	6.0
18	32	70	82	78	2.76	FLOOD	36	75	30.0	13.5
19	92	68	85	78		.13	5	53	52.9	24.3
20	93	70	87	81		.28	24	53	56.2	25.9
21	91	68	86	82	.13	.23	29	81	46.5	20.9
22	83	74	85	82	.08	.11	13	98	N/A	N/A
23	32	71	81	79	1.06	.08	21	78	25.4	11.7
24	87	72	83	80	.25	.13	24	64	39.9	18.6
25	90	67	87	79	.43	.23	21	59	48.4	22.9
26	89	71	86	82	.92	N/A	17	79	23.3	10.5
27	90	70	86	79	.07	.15	25	56	51.3	24.6
28	91	71	87	71		.25	46	67	52.4	24.6
29	92	72	88	83		.36	50	47	52.3	24.8
30	91	73	88	33	.05	.19	82	90	34.3	16.0
June Avg.										
1982	90.7	69.2	86.4	81.0	8.74	6.21**	30.9	58.1	1282.1	593.0
1981	95.5	71.3	89.4	83.5	6.79	8.32	44.0	46.9	1372.9	656.5
70yr	90.3	69.2		NORMAL	6.31					

Accumulated Rainfall Summary (Inches)

From Jan 1982	36.20
From Jan 1981	18.40
From Jan Normal	24.17

NOTE: OBSERVATION TIME IS 4:30 P.M.

*Under Centipede Sod

**27 Day Total

***Data/Campbell Micro-logger
28 Day Totals

Table 6.--continued.

JULY 1982

	Temperature (T) °F					Pan			Solar Radiation	
	Air 5'		Soil 10 cm depth*		Rain	Evap.	Wind	%RH	PAR	TOTAL
	Max.	Min.	Max.	Min.	Inches	Inches	M/da	Min.	E/m^2	MJ/m^2
1	93	72	88	82		.16	33	54	48.5	23.7
2	93	75	88	84		.24	33	54	38.2	18.7
3	95	70	89	83		.19	19	43	50.3	24.6
4	95	72	89	84		.32	34	43	43.1	21.1
5	94	70	89	85		.22	26	60	48.5	23.7
6	90	69	89	84	.16	.11	26	57	38.9	19.0
7	89	70	90	83	.19	.18	22	58	32.7	16.0
8	90	70	87	82	.05	.15	4	58	40.5	19.8
9	90	72	86	83	.28	.18	21	62	28.0	13.7
10	91	71	86	82	.05	.15	16	59	35.6	17.4
11	91	70	87	82		.15	13	70	37.4	18.3
12	91	70	88	82	.09	.19	11	62	43.0	21.0
13	93	72	90	83		.22	13	50	47.4	23.2
14	94	72	90	84		.22	19	52	51.9	25.4
15	93	74	89	84	2.20	.31	14	60	37.4	18.3
16	91	73	88	84	.04	.21	13	57	30.5	14.9
17	88	73	88	83		.16	23	67	27.8	13.6
18	90	73	86	82	.10	.13	13	72	29.2	14.3
19	90	72	84	82	1.18	.27	11	92	34.8	17.0
20	88	71	84	82	.82	FLOOD	15	68	22.3	10.9
21	88	70	82	80	.06	.07	18	69	27.0	13.2
22	88	72	85	80	.01	.12	16	69	36.6	17.9
23	91	73	86	81	.63	.21	21	62	32.9	16.1
24	90	71	84	82	.16	.17	9	64	37.6	18.4
25	92	71	87	83		.21	12	67	40.3	19.7
26	93	72	88	84	.03	.15	12	54	39.7	19.4
27	94	74	85	85	.42	.12	11	86	10.6	5.2
28	82	73	85	83	.29	.11	20	80	19.4	9.5
29	89	73	83	81	T	.13	20	58	30.5	14.9
30	91	71	85	82		.18	26	65	39.7	19.4
31	93	70	88	82		.15	28	64	41.1	20.1
July Avg.										
1982	91.0	71.6	86.9	82.7	6.76	5.38**	18.5	62.2	1121.7	548.5
1981	93.2	72.1	89.7	83.8	2.91	7.00	34.4	47.1	127.7	603.4
70yr	90.6	71.0		(Normal)	8.03					

Accumulated Rainfall Summary (Inches)

From Jan 82	42.96
From Jan 81	21.31
From Jan Normal	32.20

NOTE: OBSERVATION TIME IS 4:30 PM

*Under Centipede Sod

**30-day Average

Table 6.--continued.

AUGUST 1982

	Temperature (T) °F					Pan			Solar Radiation	
	Air 5'		Soil 10 cm depth*		Rain	Evap.	Wind	%RH	PAR	TOTAL
	Max.	Min.	Max.	Min.	Inches	Inches	M/da	Min.	E/m^2	MJ/m^2
1	93	74	88	84		.27	39	53	48.1	23.5
2	91	73	84	84	.51	.15	27	91	19.6	9.6
3	90	73	87	82	.79	.22	17	52	46.0	22.5
4	90	69	87	83		.21	15	46	35.1	21.0
5	90	71	87	83		.22	19	55	25.2	14.7
6	90	70	87	82	.16	.18	17	60	33.1	18.5
7	93	71	88	82	.01	.21	15	56	40.6	23.0
8	93	79	88	84		.07	15	57	35.4	21.0
9	91	73	88	85	.05	N/A	16	49	28.4	17.1
10	92	74	89	84		.18	13	59	27.7	16.6
11	92	66	89	83	T	.14	11	50	42.7	25.6
12	92	69	89	84	.01	.23	12	56	32.3	19.0
13	90	69	89	84	.03	.18	24	70	28.5	16.1
14	89	72	89	84		.15	31	66	28.4	16.4
15	95	69	86	82	.03	.13	16	60	30.4	20.3
16	93	70	88	83		.29	24	40	30.2	20.3
17	90	72	89	83	.54	.23	26	50	28.9	19.0
18	80	69	89	83	.13	.15	4	80		
19	83	71	82	81	.80	.01	9	80	11.2	7.9
20	90	70	85	80	T	.13	27	67	26.8	20.4
21	90	71	85	81	.20	.18	18	82	16.2	11.8
22	90	72	86	81	.05	.15	18	70	22.3	16.6
23	89	72	87	81	2.54	N/A	14	78	20.9	15.2
24	92	73	87	82	.05	.16	24	72	24.4	18.9
25	92	72	87	83		.17	25	55	24.6	18.8
26	96	75	89	84		.19	19	46	28.5	21.4
27	96	73	90	84	.14	.21	18	59	15.2	11.0
28	95	72	87	83		.11	4	49	25.9	18.6
29	95	72	88	84	.14	.20	27	59	22.3	15.8
30	88	70	87	82		.21	53	45	31.4	22.5
31	90	69	87	82		.27	44	50	30.4	21.1
August Average										
1982	90.7	71.5	87.4	82.8	6.18	5.20	20.7	59.1	860.7*	544.1*
1981	91.4	72.1	87.9*	83.2*	4.98	5.95**	36.2	54.3	1109.3	439.9
70 yr.	90.9	71.3				3.25				

Accumulated Rainfall Summary (Inches)

From Jan. 82	49.14
From Jan. 81	27.26
From Jan. Normal	32.20

NOTE: OBSERVATION TIME IS 4:30 PM

* 30 Day Average

** 29 Day Average

Table 6.--continued.

SEPTEMBER 1982

	Temperature (T) °F					Pan			Solar Radiation	
	Air 5'		Soil 10 cm depth*		Rain	Evap.	Wind	%RH	PAR	TOT.***
	Max.	Min.	Max.	Min.	Inches	Inches	M/da	Min.	E/m²	MJ/m²
1	90	69	86	81	-	.20	22	50	27.0	13.2
2	92	65	86	71	-	.18	6	45	32.0	15.6
3	94	72	87	83	-	.22	10	42	34.5	16.9
4	94	72	88	83	-	.28	16	42	34.7	17.0
5	93	71	89	84	.47	.29	25	52	25.0	12.2
6	94	70	86	82	.08	.11	20	70	13.5	9.0
7	86	68	83	80	-	.12	28	62	22.6	11.1
8	87	69	83	80	.75	.14	8	56	19.6	9.6
9	86	70	83	80	1.57		75	74	14.5	7.1
10	86	70	83	80	.95	.08	13	72	11.3	5.5
11	91	71	84	79	.30	.09	7	60	27.4	13.4
12	92	73	84	81	-	.19	2	54.	29.8	14.6
13	92	73	87	83	.10	.20	13	56	29.7	14.3
14	91	72	88	82	.07	.25	32	52	23.1	12.3
15	90	67	87	82	-	.20	26	42	26.5	13.0
16	91	71	86	82	-	.16	6	39	25.3	12.6
17	91	71	86	83	-	.19	15	37	28.4	13.9
18	91	70	85	82	-	.21	9	38	24.9	12.2
19	91	70	85	82	.62	.25	7	40	25.0	12.2
20	89	70	87	81	.29	.14	7	55	22.8	11.1
21	85	70	84	82	.30	.12	14	63	10.7	5.2
22	82	67	80	79	-	.13	15	38	23.4	11.4
23	81	59	82	77	-	.18	20	58	18.2	9.3
24	86	64	78	75	-	.18	13	55	23.0	11.2
25	84	68	79	77	.35	.16	41	70	10.3	5.0
26	77	62	77	74	.95	.07	38	59	15.5	7.6
27	84	58	78	72	-	.08	4	41	22.0	13.6
28	85	62	79	74	-	.24	29	42	29.4	13.9
29	85	65	78	74	-	.21	71	57	24.3	12.1
30	84	70	78	77	.10	.12	33	74	12.3	6.7
September Average										
1982	88.1	68.2	83.5	79.4	7.10	4.99**	22.9	53.2	705.4	344.9
1981	89.1	66.3	84.9	79.3	1.10	5.35	23.7	50.3	1060.7	524.6
70 yr.	88.7	69.4								

Accumulated Rainfall Summary (Inches)	NOTE: OBSERVATION TIME IS 4:30 PM
From Jan. 82	56.24
From Jan. 81	28.26
From Jan. Normal	46.12

* Under Centipede Sod

** 29 Day Average

Table 7. Climatological data for the greenhouse experiment.

	Temperature		Irrigation		
Day	Air Mean[‡]	Soil Mean[‡]	Water	Hoagland's solution	Solar radiation, PAR[§]
	°C		ml tube^{-1}		E m^{-2} day^{-1}
February 1983					
25[†]	19.4	14.9	1600	-	-
26	13.9	11.7	200	-	-
27	17.7	17.6	-	-	-
28	20.7	20.2	-	-	-
March 1983					
1	20.2	18.4	-	-	-
2	21.6	20.9	100	-	-
3	24.9	-	-	-	-
4	28.4	-	200	-	-
5	26.6	21.2	100	-	-
6	26.3	27.3	-	-	-
7	20.4	-	-	-	-
8	23.3	22.7	100	-	25.4
9	25.1	23.6	100	-	31.7
10	21.1	-	100	-	26.7
11	18.4	18.7	-	-	24.4
12	20.2	20.4	100	-	24.3
13	19.7	20.5	100	-	23.6
14	19.1	20.0	-	-	16.8
15	17.6	18.9	200	-	4.2
16	24.0	22.3	200	-	15.6
17	24.3	23.6	100	50	13.4
18	22.3	22.9	-	-	12.3
19	24.1	23.3	-	-	23.2
20	21.6	22.3	-	100	11.3
21	24.3	23.0	-	100	29.5
22	21.9	22.0	-	-	27.5
23	19.8	20.4	-	100	35.9
24	19.1	22.2	-	-	10.0
25	17.0	20.4	-	100	28.2
26	20.2	22.7	-	-	27.7
27	20.0	22.2	-	100	5.1
28	21.5	23.3	-	-	31.7
29	19.2	23.0	-	200	28.3
30	20.6	23.3	-	-	24.0
31	20.7	23.7	-	200	15.3

Table 7.--continued.

Day	Temperature Air Mean‡	 Soil Mean‡	Irrigation Water	 Hoagland's solution	Solar radiation, PAR§
	—— °C ——		—— ml tube^{-1} ——		— E m^{-2} day^{-1} —
April					
1†	21.3	23.6	-	-	29.3
2	21.2	23.2	-	200	11.1
3	22.4	24.9	-	-	29.9
4	22.1	24.4	-	-	30.2
5	26.0	28.1	-	200	28.7
6	27.3	29.5	-	-	21.9
7	25.4	27.6	-	200	15.8
8	24.5	25.7	-	-	7.2
9	22.5	24.0	-	400	5.7
10	23.4	25.2	-	-	29.5
11	22.6	25.6	400	-	30.4
12	23.7	25.7	200	200	28.6
13	24.9	26.4	-	400	28.7
14	23.2	25.6	200	-	19.3
15	21.9	24.0	200	-	7.9
16	18.6	22.5	-	-	29.6
17	18.7	21.8	200	-	29.3
18	18.1	21.1	200	200	12.5
19	18.3	21.4	200	200	34.8
20	18.9	21.9	-	-	20.5
21	23.2	25.4	200	200	35.9
22	24.6	25.5	-	400	39.0
23	24.3	25.9	-	20	14.4
24	26.5	25.3	-	600	22.8
25	22.9	24.6	-	-	34.5

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†Seeds were placed on February 23 into Petri dishes to germinate and seedlings were transferred on February 25 into acrylic tubes.

‡Represents means of 12 measurements taken at 2 h intervals during the day.

§Represents photosynthetic photon flux density resulting from measurements taken at 2 h intervals during the day and summed over the day assuming rectangular integration.

Table 8. Midday means of leaf water potential components, stomatal resistance and conductance for irrigated and water-stressed treatments of Pearl Early Runner.

Treatment	Days after planting	Leaf water potential	Osmotic potential	Turgor potential	Diffusive resistance	Conductance
		MPa			$s\ m^{-1}$	$m\ s^{-1}$
Optimum irrigation	55	-0.848	-1.131	+0.283	31	0.0326
	59	-0.713	-1.150	+0.437	47	0.0265
	62	-1.158	-1.420	+0.262	96	0.0177
	64	-0.943	-1.378	+0.435	35	0.0284
	68	-0.900	-1.184	+0.283	28	0.0377
	70	-0.974	-1.280	+0.306	47	0.0284
	74	-0.889	-1.134	+0.245	30	0.0343
	78	-0.816	-1.198	+0.382	63	0.0172
	81	-1.153	-1.545	+0.391	51	0.0238
	86	-0.878	-1.137	+0.259	97	0.0192
	88	-1.200	-1.475	+0.275	101	0.0151
	90	-1.134	-1.509	+0.375	96	0.0214
	94	-1.036	-1.496	+0.459	109	0.0154
	98	-1.138	-1.779	+0.641	34	0.0301
Drying cycle	55	-0.991	-0.969	-0.023	92	0.0237
	59	-0.674	-1.143	+0.468	33	0.0310
	62	-1.443	-1.415	-0.08	573	0.0024
	64	-2.227	-2.028	-0.199	1575	0.0011
	68	-2.555	-2.241	-0.314	1126	0.0014
	70	-2.288	-2.134	-0.154	1696	0.0017
	74	-2.299	-2.391	+0.090	630	0.0021
	78	-2.045	-1.967	-0.078	329	0.0121
	81	-2.661	-2.396	-0.265	933	0.0022
	86	-2.508	-2.412	-0.096	998	0.0014
	88	-2.170	-2.007	-0.163	1650	0.0015
	90	-1.472	-1.729	+0.258	126	0.0124
	94	-1.408	-1.660	+0.252	51	0.0218
	98	-1.322	-1.672	+0.350	38	0.0268

Table 9. Midday means of leaf water potential components, stomatal resistance and conductance for irrigated and water-stressed treatments of PI 383426.

Treatment	Days after planting	Leaf water potential	Osmotic potential	Turgor potential	Diffusive resistance	Conductance
		MPa			$s\ m^{-1}$	$m\ s^{-1}$
Optimum irrigation	55	-0.753	-0.872	+0.119	24	0.0412
	59	-0.657	-1.160	+0.503	34	0.0313
	62	-0.823	-1.118	+0.295	23	0.0445
	64	-0.989	-1.276	+0.287	25	0.0404
	68	-0.925	-1.104	+0.179	27	0.0378
	70	-0.755	-1.285	+0.530	107	0.0248
	74	-0.851	-1.397	+0.546	43	0.0304
	78	-1.244	-1.373	+0.129	43	0.0331
	81	-0.812	-1.190	+0.378	33	0.0310
	86	-1.270	-1.443	+0.174	69	0.0190
	88	-1.410	-1.532	+0.122	65	0.0112
	90	-0.928	-1.476	+0.548	111	0.0162
	94	-0.969	-1.601	+0.632	43	0.0284
	98	-1.427	-1.835	+0.408	28	0.0365
Drying cycle	55	-0.737	-0.691	-0.046	75	0.0269
	59	-0.794	-1.302	+0.508	109	0.0235
	62	-0.850	-1.185	+0.335	26	0.0391
	64	-1.229	-1.431	+0.202	46	0.0311
	68	-1.031	-1.372	+0.341	349	0.0247
	70	-1.132	-1.579	+0.447	83	0.0170
	74	-1.357	-1.363	+0.006	28	0.0362
	78	-1.077	-1.368	+0.290	53	0.0236
	81	-1.392	-1.541	+0.150	61	0.0191
	86	-1.178	-1.413	+0.235	121	0.0131
	88	-1.479	-1.556	+0.077	130	0.0083
	90	-1.000	-1.444	+0.445	31	0.0328
	94	-1.222	-1.436	+0.230	37	0.0319
	98	-1.137	-1.577	+0.440	28	0.0361

Table 10. Midday means of leaf water potential components, stomatal resistance and conductance for irrigated and water-stressed treatments of Early Bunch.

Treatment	Days after planting	Leaf water potential	Osmotic potential	Turgor potential	Diffusive resistance	Conductance
		MPa			$s\ m^{-1}$	$m\ s^{-1}$
Optimum irrigation	55	-0.850	-1.195	+0.345	88	0.0228
	59	-0.610	-0.888	+0.277	31	0.0330
	62	-0.824	-1.318	+0.495	26	0.0384
	64	-0.632	-1.135	+0.503	25	0.0395
	68	-0.963	-1.148	+0.186	24	0.0432
	70	-1.089	-1.360	+0.271	34	0.0327
	74	-0.881	-1.105	+0.225	25	0.0406
	78	-1.137	-1.473	+0.335	35	0.0307
	81	-1.189	-1.328	+0.139	202	0.0167
	86	-1.120	-1.342	+0.221	251	0.0080
	88	-1.463	-1.468	+0.005	112	0.0153
	90	-1.204	-1.655	+0.451	108	0.0125
	94	-1.218	-1.468	+0.250	34	0.0304
	98	-1.390	-1.772	+0.382	37	0.0198
Drying cycle	55	-0.791	-0.784	-0.007	119	0.0250
	59	-0.734	-1.023	+0.290	59	0.0357
	62	-1.006	-1.393	+0.387	11	0.0399
	64	-0.946	-1.189	+0.243	27	0.0368
	68	-1.095	-1.314	+0.218	46	0.0305
	70	-1.388	-1.481	+0.092	58	0.0179
	74	-1.464	-1.517	+0.053	27	0.0372
	78	-1.029	-1.273	+0.244	44	0.0344
	81	-1.255	-1.581	+0.326	267	0.0270
	86	-1.318	-1.639	+0.322	451	0.0051
	88	-1.572	-1.685	+0.113	93	0.0121
	90	-1.393	-1.882	+0.489	51	0.0224
	94	-1.160	-1.701	+0.541	31	0.0325
	98	-1.417	-2.009	+0.592	35	0.0300

Table 11. Midday means of leaf water potential components, stomatal resistance and conductance for irrigated and water-stressed treatments of Florunner.

Treatment	Days after planting	Leaf water potential	Osmotic potential	Turgor potential	Diffusive resistance	Conductance
		MPa			$s\ m^{-1}$	$m\ s^{-1}$
Optimum irrigation	55	-0.738	-1.190	+0.452	96	0.0217
	59	-0.852	-1.037	+0.185	38	0.0277
	62	-1.118	-1.421	+0.304	70	0.0207
	64	-1.129	-1.336	-0.207	39	0.0279
	68	-0.955	-1.162	+0.207	26	0.0391
	70	-0.827	-1.288	+0.461	33	0.0323
	74	-0.887	-1.204	+0.317	30	0.0342
	78	-0.861	-1.228	+0.367	37	0.0285
	81	-0.990	-1.504	+0.513	52	0.0208
	86	-1.005	-1.245	+0.240	52	0.0198
	88	-1.266	-1.178	-0.088	34	0.0295
	90	-1.021	-1.598	+0.577	47	0.0242
	94	-1.039	-1.658	+0.619	51	0.0245
	98	-1.596	-1.644	+0.048	40	0.0273
Drying cycle	55	-0.230	-1.019	+0.789	49	0.0253
	59	-0.689	-1.146	+0.457	31	0.0337
	62	-1.132	-1.385	+0.254	175	0.0185
	64	-0.839	-1.214	+0.376	84	0.0238
	68	-1.612	-1.629	+0.016	132	0.0172
	70	-1.233	-1.533	-0.300	67	0.0189
	74	-1.618	-1.696	+0.078	34	0.0292
	78	-1.026	-1.523	+0.497	55	0.0225
	81	-1.749	-1.748	+0.000	65	0.0197
	86	-1.394	-1.410	+0.016	185	0.0165
	88	-1.743	-1.678	-0.065	1268	0.0026
	90	-1.407	-1.830	+0.422	129	0.0106
	94	-1.362	-1.694	+0.331	81	0.0203
	98	-1.408	-1.823	+0.415	35	0.0293

Table 12. Results of the statistical analysis between the two irrigation treatments for each parameter at each sampling date.

Days after planting	Water relations parameters for each genotype									
	ψL	ψs	ψp	DR	COND	ψL	ψs	ψp	DR	COND
	Pearl Early Runner					PI 383426				
55	NS	NS	*	NS	NS	NS	NS	NS	NS	NS
59	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
62	NS	NS	NS	NS	*	NS	NS	NS	NS	NS
64	*	*	*	*	*	NS	NS	NS	NS	NS
68	*	*	*	NS	*	NS	NS	NS	NS	NS
70	*	*	*	NS	*	NS	NS	NS	NS	NS
74	*	*	NS	*	*	*	NS	NS	NS	NS
78	*	*	*	NS	NS	NS	NS	NS	NS	NS
81	*	*	NS	NS	*	*	*	NS	NS	NS
86	*	*	NS	*	*	NS	NS	NS	NS	NS
88	*	*	NS	NS	NS	NS	NS	NS	NS	NS
90	NS	NS	NS	NS	NS	NS	NS	NS	NS	*
94	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
98	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	Early Bunch					Florunner				
55	NS	*	NS	NS	NS	NS	NS	NS	NS	NS
59	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
62	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
64	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
68	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
70	NS	NS	NS	NS	*	NS	*	NS	NS	NS
74	*	*	NS	NS	NS	*	*	NS	NS	NS
78	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
81			NS	NS	NS	*	NS	*	NS	NS
86	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
88	NS	NS	NS	NS	NS	*	*	NS	NS	*
90	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
94	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
98	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

*Statistically different at $P = 0.05$ using F test; NS = nonsignificant difference between the two irrigation treatments.

Table 13. Rate of cotyledonary branch elongation for four peanut genotypes under two field irrigation treatments.

Day interval	Rate of cotyledonary branch elongation							
	Pearl Early Runner		PI 383426		Early Bunch		Florunner	
	wet	dry	wet	dry	wet	dry	wet	dry
	cm day^{-1}							
58-63	1.1	0.9	0.8	0.8	0.9	0.6	0.7	1.2
63-66	1.2	0.3	1.4	1.3	1.7	1.9	1.5	1.3
66-71	1.1	0.0	0.9	0.5	0.9	0.6	1.0	0.3
71-75	1.0	0.1	1.0	0.5	0.9	0.5	0.8	0.4
75-78	0.5	0.3	0.6	0.5	0.7	0.7	1.6	0.4
78-84	0.9	0.3	0.8	0.4	0.4	0.5	0.5	0.3
84-89	0.6	0.0	0.5	0.3	0.5	0.2	0.7	0.2
89-93	0.2	0.1	0.2	0.1	0.2	0.1	0.1	0.2
93-99	0.2	0.9	0.4	0.2	0.1	0.1	0.3	0.2

Table 14. Rate of leaf area expansion for four peanut genotypes under two field irrigation treatments.

Day interval	Rate of leaf area expansion							
	Pearl Early Runner		PI 383426		Early Bunch		Florunner	
	wet	dry	wet	dry	wet	dry	wet	dry
	$cm^2\ day^{-1}$							
58-63	12.5	18.5	8.3	10.8	11.7	26.6	9.1	19.8
63-66	33.7	16.0	34.0	16.2	37.4	21.6	42.4	22.5
66-71	33.4	8.3	16.5	28.9	29.0	19.5	26.1	28.0
71-75	34.4	5.2	22.2	18.0	6.9	15.0	24.8	15.0
75-78	31.9	0.3	19.9	23.1	17.4	5.4	19.0	11.3
78-84	23.5	1.1	15.7	12.3	13.4	10.5	18.5	19.9
84-89	27.7	6.1	13.4	10.9	11.0	9.9	6.6	4.8
89-93	8.9	17.7	7.9	4.9	5.6	6.3	16.7	4.5
93-99	14.0	15.8	3.7	3.9	4.4	7.5	8.0	12.0

Table 15. Growth of a main cotyledonary (C) branch and its ramifications (R) in Pearl Early Runner under two irrigation treatments.

after Planting	Length of branches														
	Optimum irrigation								Dry cycle						
	C	R_1	R_2	R_3	R_4	R_5	R_6	R_7	C	R_1	R_2	R_3	R_4	R_5	R_6
	cm														
58	27.05	16.08	14.98	8.93	5.03	-	-	-	31.03	17.38	17.20	10.03	-	-	-
63	32.60	18.99	19.18	10.80	6.68	-	-	-	35.38	20.75	19.00	12.45	2.50	-	-
66	36.25	24.63	24.18	13.98	9.68	3.55	1.00	-	36.15	21.60	20.40	14.25	7.03	-	-
71	41.68	29.70	31.30	21.50	14.40	4.00	2.50	-	36.33	21.95	20.48	14.90	9.05	-	-
75	45.80	33.35	35.10	24.58	17.28	8.10	5.90	-	36.70	22.85	21.48	15.85	9.75	0.63	-
78	47.25	38.15	39.33	27.03	19.60	8.98	6.45	-	37.70	23.68	22.48	16.70	10.03	2.05	-
84	52.73	39.45	43.55	30.60	22.50	10.33	9.18	4.55	39.45	24.13	23.20	17.93	10.50	2.33	1.33
89	55.98	40.38	46.85	32.45	24.18	11.05	9.80	4.73	39.55	24.33	23.78	18.53	10.83	2.40	1.33
93	57.00	41.40	48.15	33.90	25.23	11.33	10.75	5.00	39.95	25.93	24.28	19.70	12.25	3.80	1.68
99	58.05	41.78	49.43	34.58	25.93	11.43	11.43	5.23	45.35	31.95	27.90	22.53	13.88	4.45	2.13

Table 16. Growth of a main cotyledonary (C) branch and its ramifications (R) in PI 383426 under two irrigation treatments.

Days after Planting	Length of branches										
	Optimum irrigation					Dry cycle					
	C	R_1	R_2	R_3	R_4	C	R_1	R_2	R_3	R_4	R_5
	cm										
58	18.70	9.33	7.0	-	-	21.85	15.70	9.05	2.25	-	-
63	22.63	12.30	9.80	-	-	25.63	17.75	12.53	2.50	-	-
66	26.73	17.35	12.88	1.13	-	29.48	22.58	16.18	3.88	-	-
71	31.30	24.40	19.78	4.60	-	32.23	24.30	17.83	6.20	1.00	-
75	35.23	28.38	24.53	6.00	-	34.20	26.65	20.90	7.20	2.38	1.63
78	37.13	31.03	27.05	8.08	-	35.73	27.43	21.63	8.18	2.43	1.68
84	41.95	34.20	31.33	9.18	-	38.25	29.20	22.55	11.75	2.70	1.88
89	44.48	35.95	34.78	10.30	11.8	39.85	30.58	23.15	13.40	2.70	2.13
93	45.40	36.85	35.90	10.85	21.8	40.25	32.10	23.90	14.20	2.70	2.20
99	47.90	38.38	37.73	11.08	26.3	41.30	33.28	24.15	15.38	3.33	2.48

Table 17. Growth of a main cotyledonary (C) branch and its ramifications (R) in Early Bunch under two irrigation treatments.

Days after planting	Length of branches						
	Optimum irrigation			Dry cycle			
	C	R_1	R_2	C	R_1	R_2	R_3
	cm						
58	27.38	17.95	10.93	30.78	22.93	15.38	8.05
63	32.13	22.33	11.58	33.88	25.38	19.13	8.73
66	37.10	27.60	14.63	39.55	32.20	24.23	9.55
71	41.70	32.25	18.58	42.73	36.08	27.80	10.60
75	45.50	35.93	21.23	44.88	37.13	30.25	10.95
78	47.68	38.25	22.80	46.98	38.35	31.33	11.18
84	50.13	41.28	25.63	49.95	39.90	33.55	11.18
89	52.48	41.98	25.83	51.18	41.38	34.28	11.65
93	53.30	42.10	26.55	51.63	41.80	34.50	11.95
99	53.75	43.18	27.35	52.38	42.63	34.85	12.05

Table 18. Growth of a main cotyledonary (C) branch and its ramifications (R) in Florunner under two irrigation treatments.

Days after planting	Length of branches												
	Optimum irrigation						Dry cycle						
	C	R_1	R_2	R_3	R_4	R_5	C	R_1	R_2	R_3	R_4	R_5	R_6
	cm												
58	28.75	15.00	12.93	6.35	-	-	29.15	22.05	17.00	13.30	6.13	-	-
63	32.20	20.70	15.43	10.00	-	-	35.38	24.88	20.88	15.68	7.50	-	-
66	36.75	25.20	18.10	15.10	4.50	1.00	39.25	28.65	29.98	19.38	9.73	-	-
71	41.85	29.80	23.73	18.83	9.33	1.90	40.68	29.93	30.40	20.80	9.98	-	-
75	45.10	32.63	26.28	21.85	10.48	1.90	42.18	31.95	34.03	22.78	10.90	1.18	-
78	49.78	33.48	27.33	22.78	11.48	3.20	43.45	33.18	35.73	23.78	11.68	2.08	-
84	52.83	35.38	29.83	26.08	12.38	6.40	45.08	35.60	37.48	24.95	12.20	2.28	1.70
89	56.40	38.20	32.15	27.95	13.03	7.83	46.33	36.78	38.05	25.45	12.90	2.60	1.90
93	56.83	42.73	33.65	29.15	14.63	9.13	47.20	38.08	39.25	26.03	13.15	2.60	1.90
99	58.58	44.80	34.95	30.25	15.23	9.35	48.43	39.60	40.13	27.18	13.88	2.63	1.95

Table 19. Means and standard errors of root length density at 64 days after planting for four peanut genotypes under two field irrigation treatments.

	Root length density at seven soil depths							
	Pearl Early Runner		PI 383426		Early Bunch		Florunner	
Depth	wet	dry	wet	dry	wet	dry	wet	dry
— cm —	cm cm^{-3}							
15	0.563±0.092*	0.650±0.123	0.395±0.095	0.560±0.147	0.580±0.026	0.450±0.121	0.587±0.086	0.700±0.170
30	0.453±0.040	0.433±0.104	0.347±0.077	0.265±0.054	0.473±0.147	0.527±0.067	0.515±0.127	0.587±0.142
45	0.113±0.057	0.235±0.067	0.183±0.078	0.165±0.042	0.330±0.180	0.290±0.143	0.253±0.079	0.297±0.090
60	0.155±0.031	0.317±0.056	0.223±0.085	0.300±0.080	0.213±0.134	0.487±0.340	0.125±0.022	0.213±0.054
90	0.105±0.025	0.110±0.028	0.137±0.039	0.333±0.142	0.213±0.071	0.380±0.104	0.123±0.044	0.173±0.063
120	0.070±0.039	0.110±0.048	0.190±0.056	0.257±0.104	0.193±0.138	0.200±0.087	0.185±0.055	0.135±0.072
150	0.027±0.010	0.160±0.031	0.060±0.027	0.177±0.056	0.363±0.215	0.145±0.075	0.127±0.036	0.155±0.082

*Mean ± standard error of the mean.

Table 20. Means and standard errors of root length density at 89 days after planting for four peanut genotypes under two field irrigation treatments.

	Root length density at seven soil depths							
	Pearl Early Runner		PI 383426		Early Bunch		Florunner	
Depth	wet	dry	wet	dry	wet	dry	wet	dry
— cm —	cm cm^{-3}							
15	1.422±0.122*	0.890±0.196	0.713±0.069	0.795±0.152	0.917±0.063	0.760±0.124	0.660±0.075	0.957±0.261
30	1.087±0.117	0.600±0.066	0.733±0.126	1.025±0.054	0.963±0.020	0.880±0.146	1.017±0.244	1.002±0.160
45	0.310±0.047	0.320±0.056	0.335±0.053	0.275±0.025	0.373±0.078	0.660±0.128	0.257±0.046	0.397±0.097
60	0.362±0.067	0.240±0.020	0.392±0.061	0.503±0.017	0.293±0.061	0.710±0.062	0.287±0.093	0.450±0.195
90	0.295±0.055	0.160±0.016	0.357±0.049	0.367±0.028	0.337±0.019	0.537±0.115	0.170±0.033	0.405±0.017
120	0.207±0.021	0.150±0.025	0.265±0.047	0.253±0.014	0.350±0.021	0.553±0.043	0.197±0.014	0.405±0.050
150	0.137±0.044	0.053±0.014	0.125±0.017	0.167±0.029	0.417±0.033	0.547±0.164	0.103±0.026	0.385±0.040

*Mean ± standard error of the mean.

Table 21. Means and standard errors of root length density (RLD) and root dry weight (RDW) at nine tube depths for four peanut genotypes grown in a greenhouse.

Depth	Pearl Early Runner		PI 383426		Early Bunch		Florunner	
	RLD	DWR	RLD	DWR	RLD	DWR	RLD	DWR
—cm—	—cm cm^{-3}—	—g—	—cm cm^{-3}—	—g—	—cm cm^{-3}—	—g—	—cm cm^{-3}—	—g—
20	9.135±0.712*	1.404±0.125	5.608±0.655	1.040±0.071	9.386±0.903	1.571±0.090	7.166±0.091	1.264±0.027
40	2.732±0.375	0.226±0.026	2.922±0.431	0.233±0.012	5.508±0.285	0.484±0.027	3.440±0.430	0.308±0.029
60	2.102±0.310	0.146±0.014	1.972±0.331	0.181±0.008	3.372±0.306	0.319±0.022	2.852±0.197	0.197±0.014
80	1.312±0.116	0.111±0.016	2.344±0.235	0.200±0.013	4.030±0.245	0.318±0.030	2.696±0.536	0.183±0.018
100	0.438±0.168	0.045±0.016	1.340±0.346	0.158±0.016	2.580±0.353	0.344±0.051	1.242±0.170	0.120±0.014
120	0.176±0.150	0.022±0.017	0.729±0.241	0.094±0.035	0.824±0.372	0.155±0.038	0.464±0.212	0.073±0.020
140	0.035±0.035	0.005±0.005	0.158±0.101	0.029±0.014	0.432±0.339	0.052±0.039	0.040±0.026	0.014±0.008
160	0.012±0.012	0.003±0.003	0.002±0.002	0.001±0.001	0.051±0.036	0.016±0.011	0.002±0.002	0.002±0.002
180	0.000±0.000	0.000±0.000	0.000±0.000	0.000±0.000	0.004±0.004	0.002±0.002	0.000±0.000	0.000±0.000

*Mean ± standard error of the mean.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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